HOME OFFICE

CIVIL DEFENCE

Manual of Basic Training

VOLUME II

ATOMIC WARFARE

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GENERAL PREFACE

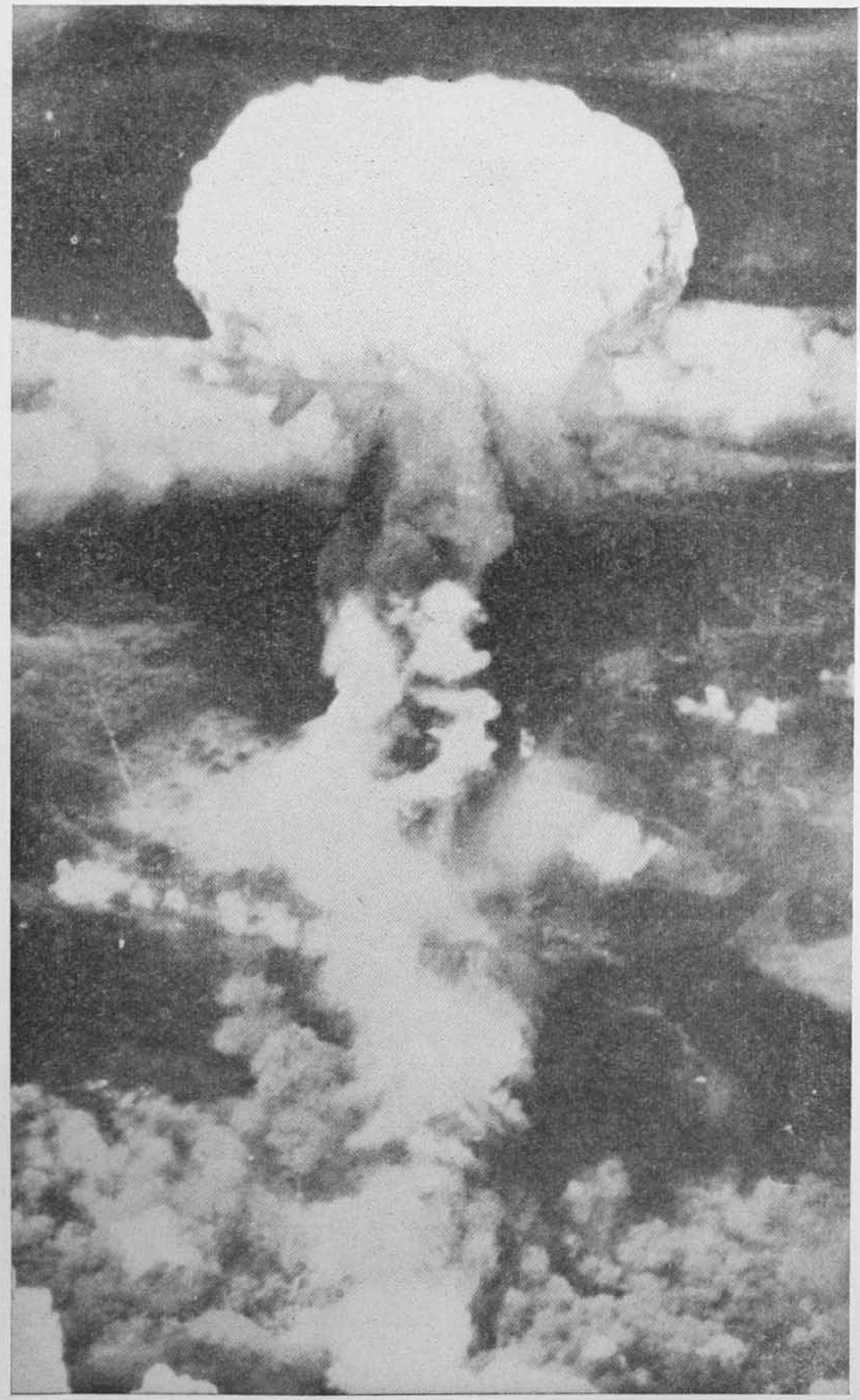
The series of Civil Defence handbooks and pamphlets is produced under the authority of the Home Secretary by the Civil Defence Department of the Home Office with the assistance of and in co-operation with the Secretary of State for Scotland and other Ministers concerned.

Measures for safeguarding the civil population against the effects of war which these publications describe, have become an essential part of the defensive organisation of this country. The need for them is not related to any belief that war is imminent. It is just as necessary that preparations for Civil Defence should be made in time of peace as it is that preparations should be made for the Armed Forces.

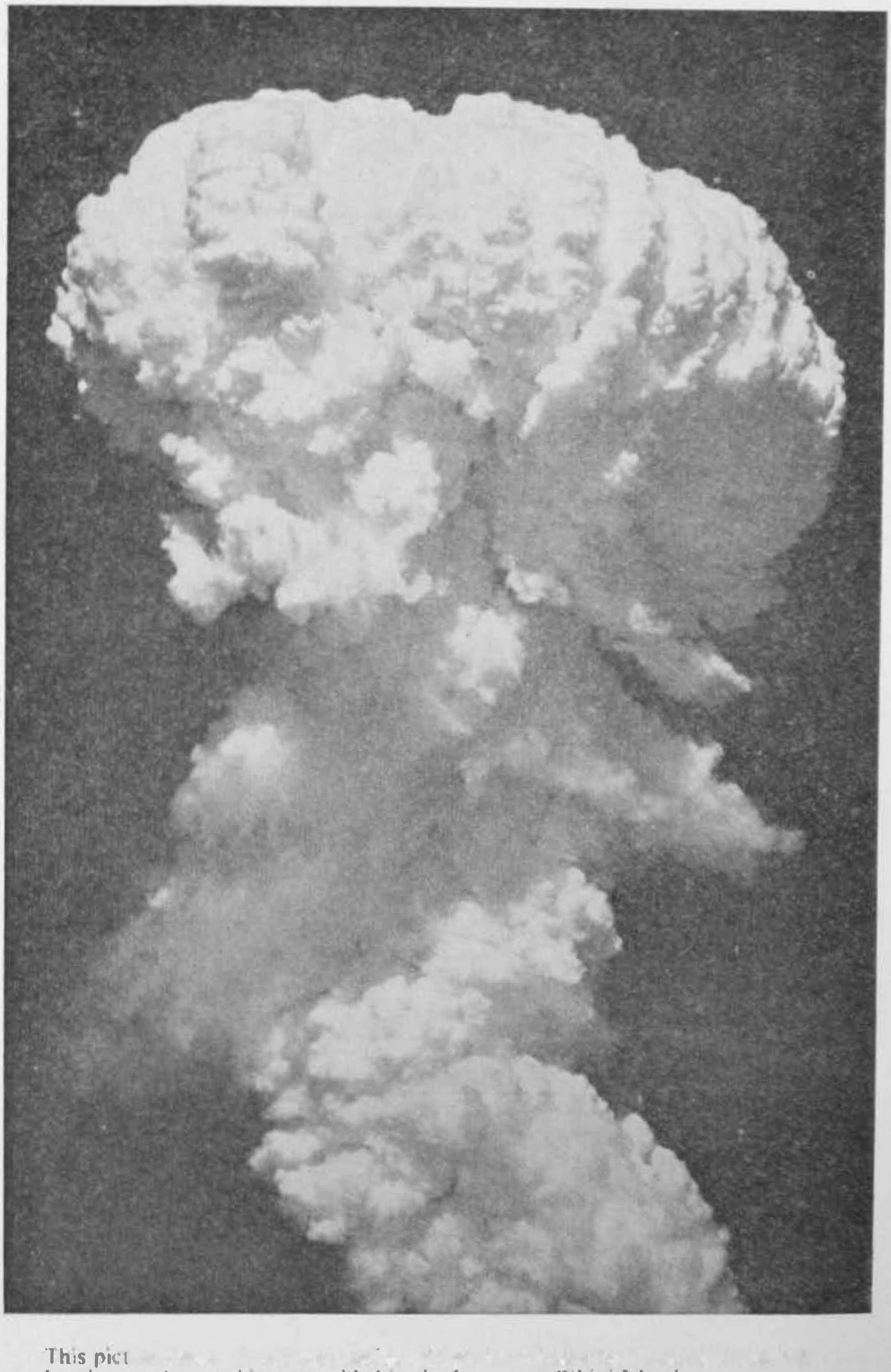
The publications cover, as far as is possible, measures which can be taken to mitigate the effects of all modern forms of attack. Any scheme of Civil Defence, if it is to be efficient, must be up-to-date and must take account of all the various weapons which might become available. The scale of bombing experienced in Great Britain during the 1939-45 war might be considerably exceeded in any future war, and types of weapons and tactics which were not experienced in this country might conceivably be used against it in the future. It does not follow that any one of the weapons, e.g., the atomic bomb, will necessarily be used, and it is most important that a proper balance is held between what is likely and what is possible.

The use of poison gas in war was forbidden by the Geneva Gas Protocol of 1925, to which this country and all the other countries of the Western Union were parties. At the outbreak of a war, His Majesty's Government would try to secure an undertaking from the enemy not to use poison gas. Nevertheless the risk of poison gas being used remains a possibility and cannot be disregarded any more than can certain further developments in other scientific fields.

The publications are designed to describe not only precautionary schemes which experience in the last war proved to be extremely effective in preventing avoidable injury and loss of life, or widespread dislocation of national industries, but also the training, both technical and tactical, which will be required of the personnel of the Civil Defence Corps if they are to be ready effectively to play their part if war should ever break out. The publications aim at giving the best available information on methods of defence against all the various weapons. Information is not complete in respect of some of these weapons and the best methods of countering them, but as results of experimental work and other investigations mature, they will be revised and added to from time to time so that the Civil Defence Corps may be kept up-to-date and training may be on the most modern and experienced lines.



This picture shows the mushrooming of the column of smoke which rose 60,000 feet into the air over the Japanese port and industrial centre of Nagasaki.



This pict
bomb over the warships assembled in the lagoon at Bikini Island.

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NOTE

The pagination of this pamphlet is not continuous as it may be necessary to introduce new pages at a later date.

FOREWORD BY THE PRIME MINISTER

The object of this pamphlet is to provide all members of the Civil Defence Corps and other Services associated with Civil Defence with a short manual of practical information about the atomic bomb and its effects. It is, of course, our earnest hope that we shall never have to experience the horrors of an atomic attack. The tremendous force of atomic power should be used for industrial and humanitarian purposes and not for mass destruction. Ever since the Washington Declaration, which I signed with the President of the United States and the Prime Minister of Canada in November 1945, the United Kingdom has pressed for international agreement to ensure that atomic energy should be used only for peaceful purposes. But any such agreement would be illusory without the most rigorous system of international control. Although nearly two years ago nine out of the eleven members of the United Nations Atomic Energy Commission agreed on what they considered to be a really effective plan for the control of atomic energy and although this plan was subsequently approved by the overwhelming majority of the General Assembly of the United Nations, the Soviet Union has so far refused to accept it, and has instead put forward counter-proposals which were rejected in the Commission by a nine to two vote on the ground that they did not provide an adequate basis for effective international control. We shall not, however, abandon our hope that an effective system of international control may ultimately be adopted by the United Nations, and we for our part will certainly do all in our power to make such an agreement possible. In the meantime we must proceed with our Civil Defence preparations on the basis that, in the event of war, we might be subjected to atomic attack and with the object of minimising the casualties which must inevitably accompany such an attack.

June, 1950.

C R Attlee

ATOMIC WARFARE

INTRODUCTION

This pamphlet is based on the known effects of the type of bombs used against the two Japanese cities of Hiroshima and Nagasaki.

Many people must have said to themselves, and, indeed, must still be saying: " What is the good of doing anything against this weapon? There can be no defence against the atomic bomb." No complete defence can be provided against any weapon of war, but just as it proved possible to devise means of mitigating the consequences of other forms of attack in the last war, so it is certain that means can be found of mitigating the consequences of atomic warfare. It is one of the aims of this pamphlet to try and put the whole matter into proper perspective and to show, as is indeed the truth, that there are to-day a great many practical steps that will greatly reduce the casualty producing power of this bomb. And it is confidently hoped, as time goes on and knowledge increases, that the defence can be steadily improved. The introduction of the atomic bomb into warfare represented a great and unparalleled jump in the power of a single offensive weapon. It is the business of defence to catch up, as it has always caught up; and great efforts have been and are being directed to this end. Of the three major effects produced when an atomic bomb explodes, two—blast and flash-burn—are not new although they have their own special characteristics. The third—radiological effect—is novel in character and in its results, and there will, therefore, be a natural tendency to give it special prominence. But it is most important that a correct balance should be maintained, a point which instructors should specially note. **Some of the radiological effects, although they must be taken into account, will not normally be experienced; nor should they necessarily prove a serious hazard to operations if they were encountered.**

There are many problems to which, at present, only imperfect or partial solutions can be given. As knowledge increases, so will these gaps gradually be filled. And while the situation that might be created by the use of atomic bombs would be of the utmost severity, involving many casualties and heavy destruction to property, it can be said with confidence that the defensive measures which are being and will continue to be gradually developed, backed up by sound teaching and good training will enable the effects to be greatly reduced.

It would be outside the scope of this pamphlet to deal with the general Civil Defence measures which might provide protection against or mitigation of the consequences of an atomic bomb. The measures which proved effective in the last war, such as the warning system, the provision of shelters, schemes of dispersal and measures for preventing the spread of fire, would undoubtedly reduce casualties and damage under conditions of atomic warfare.

Appendix I deals briefly with the elements of nuclear physics, and is included in the hope that it will help all concerned to a better understanding of the practical problems which this new weapon has produced. For those who may wish to study further the science of nuclear physics many publications already exist. But such studies are not essential for ordinary Civil Defence purposes, and the aim has been to describe, in this pamphlet, only the major results experienced when an atomic bomb is burst, and the counter-measures which may be taken against them.

CHAPTER I

FEATURES OF ATOMIC EXPLOSION

1. Methods of Attack

Atomic bombs might be exploded on the ground, under water, low in the air, or high in the air.

With the high air burst bomb, the material damage on the target area is the most widespread. With the low air burst bomb the area affected would be smaller but the material damage more intense. With an under water burst, the maximum area of contamination would be experienced.

There is little doubt that the high air burst bomb is the most effective against a normal target, i.e. a well built up area, since the maximum blast effect will be experienced. There may be special circumstances, connected with a particular target, which would merit a variation of these tactics, but they would be the exception rather than the rule.

2. General Description of Explosion

When an atomic bomb explodes in the air, a ball of fire several hundred feet in diameter results. From this a dazzling flash of light, intense heat, and various forms of radioactivity shoot out in all directions, followed by blast and sound waves. The light, heat and radioactive effects begin to arrive at the target area on the ground some seconds before the slower moving blast and sound waves, while the radioactive "fission" products, into which the material of the bomb breaks up on explosion, arrive still later, if at all.

The ball of fire, quickly losing brilliance, rises up in the air, with the ascending hot gases produced by the explosion, in a column, first multicoloured and then white, of swirling gas and particles. This column rises to a height of many thousands of feet and billows out giving the appearance of a huge mushroom on its stalk. On the ground below, where the blast has hit, the scene is obscured by a cloud of dust and smoke.

3. Dangers Resulting from Explosion

The enormous energy released from the explosion of an atomic bomb takes three main forms capable of causing damage to materials and danger to persons. These are Heat, Radioactivity and Blast.

Heat flash and blast, though much more intense and of much greater range in the case of the atomic bomb, are already known in warfare in connection with high explosive weapons; but radioactivity is a new effect peculiar to the atomic weapon and produces an immediate danger at the time of explosion. It might also, under suitable circumstances, subsequently give rise to persisting danger from contamination or irradiation of ground or materials.

Taking these forms of effect in the order of their arrival on the target, a brief description is given of each and is followed in succeeding chapters by a detailed consideration of the damage and danger they may cause to property and persons, and some of the problems they will create for Civil Defence.

(i) *Heat Flash:* On the explosion of the bomb a wave of intense heat called "heat flash" radiates in all directions. The rays travel in straight lines at the speed of light (186,000 miles per second) and are so intense that the surface of objects just underneath the ball of fire are raised in temperature by many thousands of degrees. Even at distances of five miles, the flash is sufficiently intense to produce a feeling of bodily warmth. This heat flash lasts only about a second and has no great penetrating power.

The heat flash, however, is capable of directly igniting inflammable material such as dark cloth, paper, and dry rotted wood (as it did in Japan), thereby starting immediately many fires simultaneously over a wide area. Isolated instances of the starting of such primary fires were reported at distances of nearly two miles from the centre of damage (ground zero) and many buildings near to the centre, which survived the blast effect, were gutted by fires started by the heat flash which entered through windows and open doors and ignited inflammable contents. The surface of many materials which do not normally show visible signs of heat was affected, roof tiles were blistered, polished granite roughened, and concrete reddened at distances varying from half to one mile from ground zero.

These details are given to emphasize the range and degree of heat flash, but it will be appreciated that in a country like ours, where the great majority of buildings are of brick, stone or concrete, the risk of large numbers of fires being started by heat flash is much less than it was in Japanese cities.

When to the fire-raising dangers of the heat flash are added those of secondary fires which normally occur following the collapse of buildings on domestic fires, the breaking of gas mains, and the damage to electricity communications resulting from blast, it will be seen that the atomic bomb is a potent fire-raising weapon. And it will be necessary to increase precautions against fire, particularly as regards the inflammable contents of otherwise fire resisting buildings.

(ii) *Radioactivity (Immediate Danger):* When an atomic bomb explodes radioactivity is given off in all directions in the form of radiation called "gamma" rays and as particles called "neutrons". The bomb material itself also splits up into radioactive dust known as "fission products".

(a) *Gamma Rays:* These rays travel at the speed of light and are scattered in the air and reflected from nearby objects in much the same way as are light rays. Thus, although the most intense beam of gamma rays is the direct one from the ball of fire, there is nevertheless some gamma radiation from every
sky, just as in strong sunlight a room which faces north still receives light from the visible sky and by reflection from other objects. Most of the gamma rays are emitted in the first few seconds. The intensity decreases rapidly as time goes on and as the emitting material moves away by rising in the ball of fire. After one minute there is little danger from gamma rays. Judging from experience

of high air burst bombs in Japan (i.e. those causing the most wide-spread damage) the effective danger range from these bombs appeared to be about one and a quarter to one and a half miles from the centre of damage.

Gamma rays have very great powers of penetration and will go through considerable thicknesses of building and other materials. They will readily enter the human body and are very damaging to it. They do not, however, render radioactive the materials which they penetrate, and their intensity is reduced in the process. So far as is known at present, no form of clothing will give protection against gamma rays, but a large measure of immunity can be obtained by structural precautions of a conventional character. This is more fully discussed in Chapter III.

Unprotected persons within half a mile of ground zero would receive a fatal dose of radiation and, at about three quarters of a mile, half might die. Beyond this range the intensity of the rays falls off and there should be relatively few deaths; but lesser effects of radiation, such as loss of hair, might be expected up to one and a half miles. In Japan 15-20 per cent. of fatal casualties were attributed to gamma rays, but the percentage might have been higher had the casualties survived other injuries. (See Fig. 1.)

The figures set out in the preceding paragraph are those given as an estimate by the British Mission from the experience of the high air burst bombs used in Japan and under similar conditions would apply to persons in a British city. *It must be stressed however that they apply to persons caught in the open with no warning or suitable shelter*, and that even ordinary houses will give some degree of protection by lessening the intensity of the rays that penetrate them.

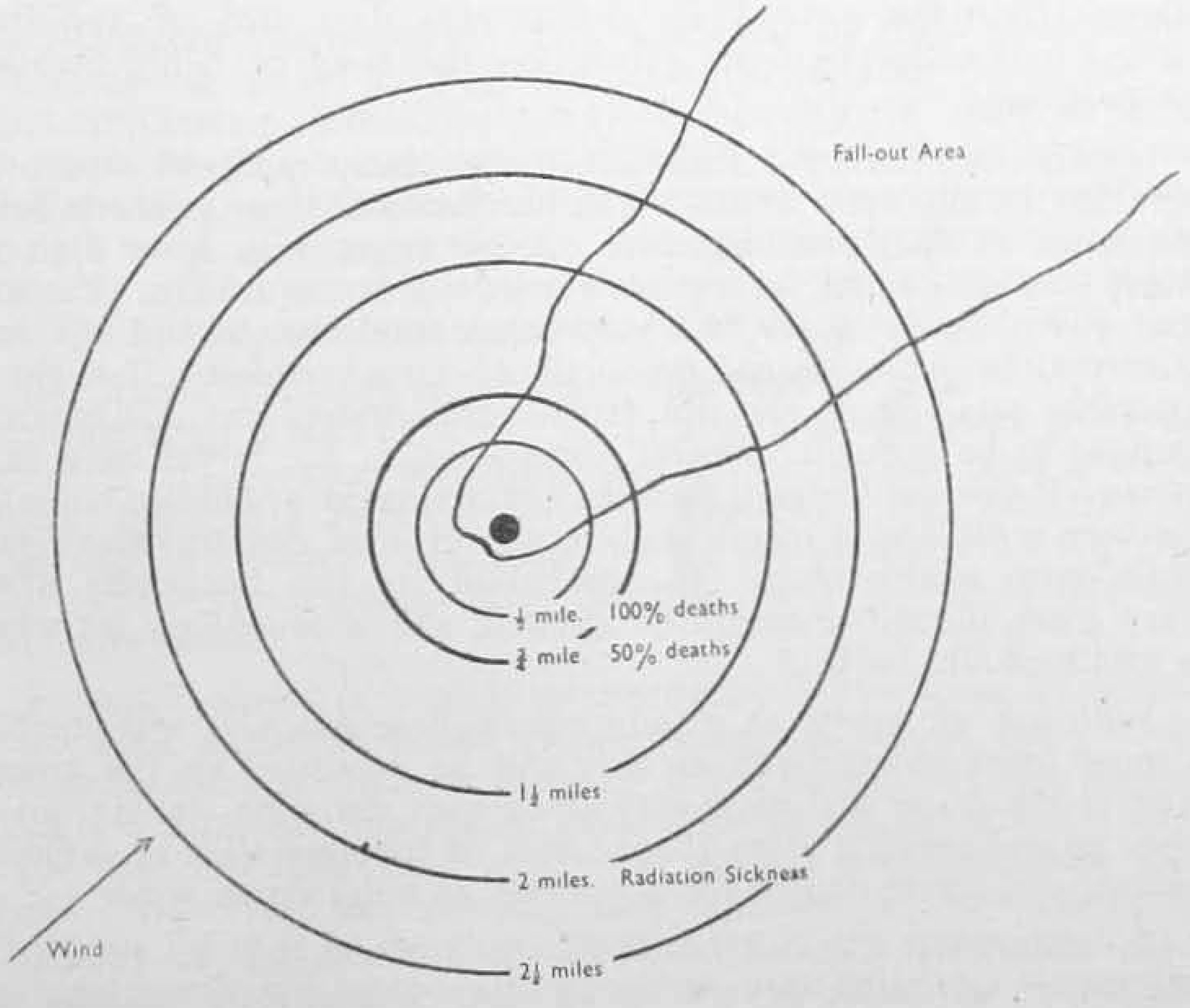

FIG. 1. Radii of Gamma Flash.

(b) *Neutrons:* These are the other form of penetrating radiation producing immediate danger at the time of explosion. They are minute particles emitted from the split nuclei of the atoms at the time of explosion, and they travel at great speed in all directions reaching the ground, if near enough to it, almost at once. The duration of their emission is short, probably not more than a few seconds. Their lethal range too is much shorter than that of gamma rays, and it is probable that the dangers associated with them will come only with the other forms of atomic attack, rather than from high air burst bombs.

Neutrons have great powers of penetration both of materials and of the human body to which they are injurious, but at the time they are not felt. They differ from gamma rays in that they render radioactive many materials which they penetrate. This form of radioactivity is called "induced" and can persist for considerable periods depending on the material irradiated.

The casualties likely to occur from neutrons alone are difficult to estimate but except close underneath an air burst bomb the thickness of concrete sufficient to give protection against gamma rays would also give protection against neutrons. It must be remembered that probably the most important factors in causing fatal casualties within the neutron range are from the effects of blast, i.e. collapse of buildings, heat flash and gamma ray flash. It is possible, however, that there might be danger from some induced and persisting radioactivity which neutrons produce in other materials.

(iii) *Radioactivity (Delayed Danger):* In the preceding paragraphs some mention has been made of "fission products" and of neutrons causing "induced" radioactivity in materials which they penetrate. These two forms of radioactivity produce "delayed" danger from the penetrating gamma rays they give off and from actual radioactive particles getting on the body or being breathed or swallowed.

(a) *Fission Products:* These are the intensely radioactive particles resulting from atomic fission. **The likelihood of these products being deposited in dangerous amounts on the target area from high air burst bombs is small.** They are carried up in the column of smoke and ascending hot gases to a very considerable height and are there dispersed by the winds and eventually become harmless. It might be possible, while they are still fairly concentrated, for a dangerous deposit to be brought to earth down wind of the target by a rainstorm. If this did happen, the area contaminated would not normally be very great and it might easily occur in open country where very little harm might result. The probability of this happening is not very great, though it cannot be ignored, and is something for which a watch should be kept.

With low air bursts or ground bursts these products will create a danger from radioactivity as they will be deposited on the ground and in the crater and may drift along with the wind, falling out as they go and creating a fan shaped area of contamination of sufficient intensity to cause danger for a number of miles down wind.

In underwater explosions the fission products will be present in the water and mist thrown up and can contaminate persons and objects over several square miles.

Areas contaminated by fission products or induced radioactivity will remain radioactive after the explosion, emitting penetrating gamma rays and giving rise to danger from actual radioactive particles getting on to the body or being breathed or swallowed. Exposure to atmospheric conditions, heat, chemical treatment, etc., will have no effect in destroying them. If an element is radioactive it will decay normally according to its specific " half life " which may be a few seconds or many years. " Half life " is the term used to indicate the length of time it takes for a radioactive element to lose half its radioactivity by natural decay.

As many different elements with different half lives may be involved in causing radioactive contamination, and as the intensity of the danger will also vary with many factors such as height of explosion, climatic and meteorological conditions, the nature and composition of the ground, etc., it is not possible to say in advance how long a contaminated area will remain dangerous ; but in exceptional circumstances it may be some time before it could be safely re-occupied.

The high initial intensity, however, will fall very quickly and allow rescue parties, fire fighters and other Civil Defence workers to enter contaminated areas and carry out essential work normally without any special protective clothing though the time they stay there may have to be limited in accordance with a certain maximum permissible radiation dose, which is now being investigated and will be announced in due course.

Though radioactivity is unseen and unfelt, its presence can be detected and its intensity measured by instruments which are described in a later chapter ; as is also the outfit which would be worn to prevent fission products getting on the body.

(b) *Induced Radioactivity:* This is caused by the neutrons given off from the nuclei of the split atoms penetrating materials and rendering certain of them radioactive and dangerous. As with fission products the danger only occurs with low air or ground bursts, and will, in effect, increase by a small proportion the radioactive danger caused by the fission products. This induced radioactivity is also found in underwater bursts ; but the induced radioactivity is usually masked by the enormous radioactivity of the fission products.

(iv) *Blast :* The difference between the blast from an atomic bomb and that from a high explosive bomb is that, at a distance from each at which the *pressures* are equal, the *duration* of the blast from the atomic bomb is a hundred or more times longer than that from the high explosive bomb. This results in the mechanism of damage from the atomic bomb being quite different from that from the high explosive bomb.

Figure 2 shows a typical pressure-time curve from a medium sized high explosive bomb at a distance at which fairly severe structural damage would be caused. It will be seen that the pressure rises to a value of 15 lb./sq. in. (over 2,000 lb./sq. ft.) which is much more than the *static*

stand. However, this pressure only lasts for a very short time (1/10 sec.) and it is therefore much more in the nature of a blow suddenly delivered to the structure than a static load. The ability of a suddenly applied blow to cause damage is determined both by the pressure and by the time for which it acts. In fact it is the product of these two (known as the " impulse ") which measures the damaging ability of the blast from a normal high explosive bomb. This point can easily be demonstrated on an ordinary door. If the door is unlatched it can be pushed open by a force of a few ounces applied somewhat slowly by the little finger. However, if the door is struck quite a hard sharp blow with the fist it will not move very far, even though the instantaneous force between the fist and the door (corresponding to the blast pressure) may have been many pounds. In fact if the door is hit hard enough it is quite likely to be torn off its hinges, and this, of course, is just what high explosive blast does. It gives things a hard sharp blow rather than a gentle push, and many of the so-called freaks of blast can quite easily be explained once this point is fully appreciated.

Again it will be seen from Figure 2 that the pressure, or positive, phase of the blast is followed by a negative or suction phase. Although the suction in this negative phase is only about $\frac{1}{3}$ of the pressure in the positive phase, the duration is about 3 times as long, and therefore the *impulses* in the two phases are approximately equal. Hence their potential abilities to cause damage are also approximately equal. However, since the suction phase occurs last, there is a tendency for its effects to be the more noticeable. For example, the wall of a building may be badly cracked in the pressure phase and may then collapse outwards in the suction phase.

If the impulse criterion [illegible] be expected to demolish 9-inch brick walls to a distance of over 10 miles. However, at this distance from the atomic bomb the peak pressure is only about 0.1 lb./sq. in. [illegible] the static strength of the wall, and consequently, however long this pressure is applied, it cannot hurt the wall. It will thus be seen that the impulse criterion breaks down for the atomic bomb. The position is that the blast impulse is only the criterion of damage so long as the maximum blast pressure is substantially greater than the static strength of the target, and this is not the case at the limits of damage to normal structures with an atomic bomb. With the atomic bomb, therefore, blast pressure rather than impulse tends to be the criterion of damage. If the effective blast pressure exceeds the static strength of the structure failure must be expected, whereas if it is less no failure can occur however long the duration of the blast. In fact, atomic bomb blast is more like strong wind than the sudden blow which represents the effects of high explosive blast, and many of the failures observed at Hiroshima and Nagasaki resembled closely the kind of damage that might be done to buildings by a very strong wind.

The reason for the absence of suction damage at Hiroshima and Nagasaki should now be clear. As stated earlier the *impulses* in the positive and negative phases are about equal, so that if blast impulse is the criterion of damage many cases of suction failure must be expected. However, the *pressure* in the positive phase is 3 or 4 times as great as in the negative, so that when pressure is the criterion of failure, few, if any, suction failures are to be expected. If a building does not fail under the pressure phase it is rather unlikely to fail under the much lower pressures in the suction phase.

The blast damage from an atomic bomb (and also from a large high explosive bomb) can be increased by bursting the bomb above ground level. The pressure wave from the bomb is then reflected by the ground and, since the reflected wave is travelling through air that has been compressed and heated by the direct wave, it tends to travel faster than, and to catch up with, the direct wave. Where the reflected wave catches up with the direct wave the two coalesce to form what is called a Mach wave and it is the formation of this wave which accounts for the increase in damage due to the air burst.

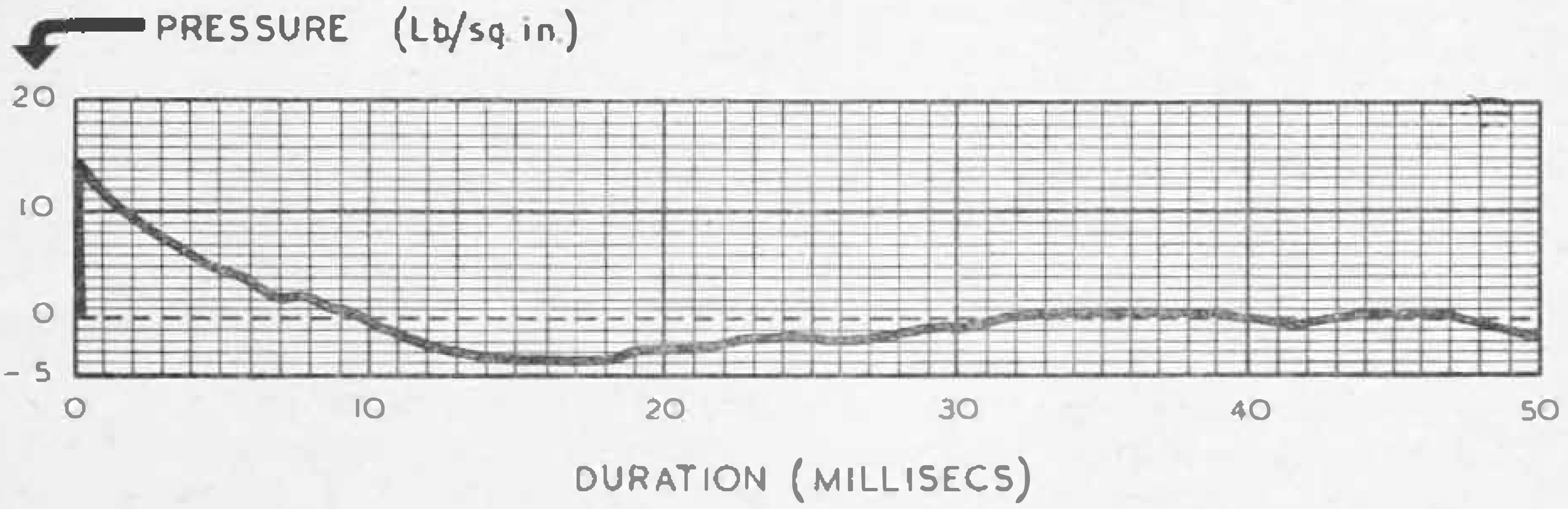

FIG. 2.

4. Casualty Considerations

The causes of casualties from the atomic explosion would be flash burns, radioactivity, ordinary fire burns and mechanical injuries from falling masonry and flying debris. Estimates of the percentage causes of death as assessed on experience in Japan is:—Heat Flash 20-30 per cent., Gamma Rays 15-20 per cent., and Mechanical Injuries and Burns 50-60 per cent.

5. Estimates of Casualties in a British City

If the people in our cities were caught, as were the Japanese, without warning, before any evacuation had taken place, and with no suitable shelters, the casualties caused by a high air burst bomb would be formidable. The British Mission to Japan estimated that *under these circumstances* as many as 50,000 people might lose their lives in a typical British city with a population density of 45 persons to the acre. Much can be done, however, to mitigate the effects of the bomb and to save life, and it is certain that with adequate advance preparations, including the provision of suitable shelters and with good Civil Defence services, the lives lost could be reduced to a fraction of the number estimated by the British Mission.

CHAPTER II

HEAT FLASH

10. Effects on Persons

The effects of heat flash on unprotected people will be severe. The nearer to ground zero the greater the danger ; those at ground zero would be killed. Severe third degree burns would result up to about 1 mile and burns of lesser intensity up to 2½ miles. In Japan 20-30 per cent. of fatal casualties were attributed to flash burn. A similar proportion is to be expected in Britain if there is no warning and people are caught in the streets. (See Fig. 3.) If, however, there is enough warning for the population to take cover and they do so, the number of fatal casualties from flash burn should be relatively small.

The duration of the heat flash is very short, probably not more than about a second or two. Moreover the rays travel in straight lines. Protection is therefore relatively easy and will be given by any form of building ; while even clothing, though it may itself become ignited, affords some degree of protection for the skin underneath, particularly if not in close contact with the body, and especially if of a light rather than a dark colour. This colour differentiation only applies, however, at distances where the heat intensity has fallen below that which would fire the fabric as a whole. Fog and mist reduce the distances to which flashburn is experienced.

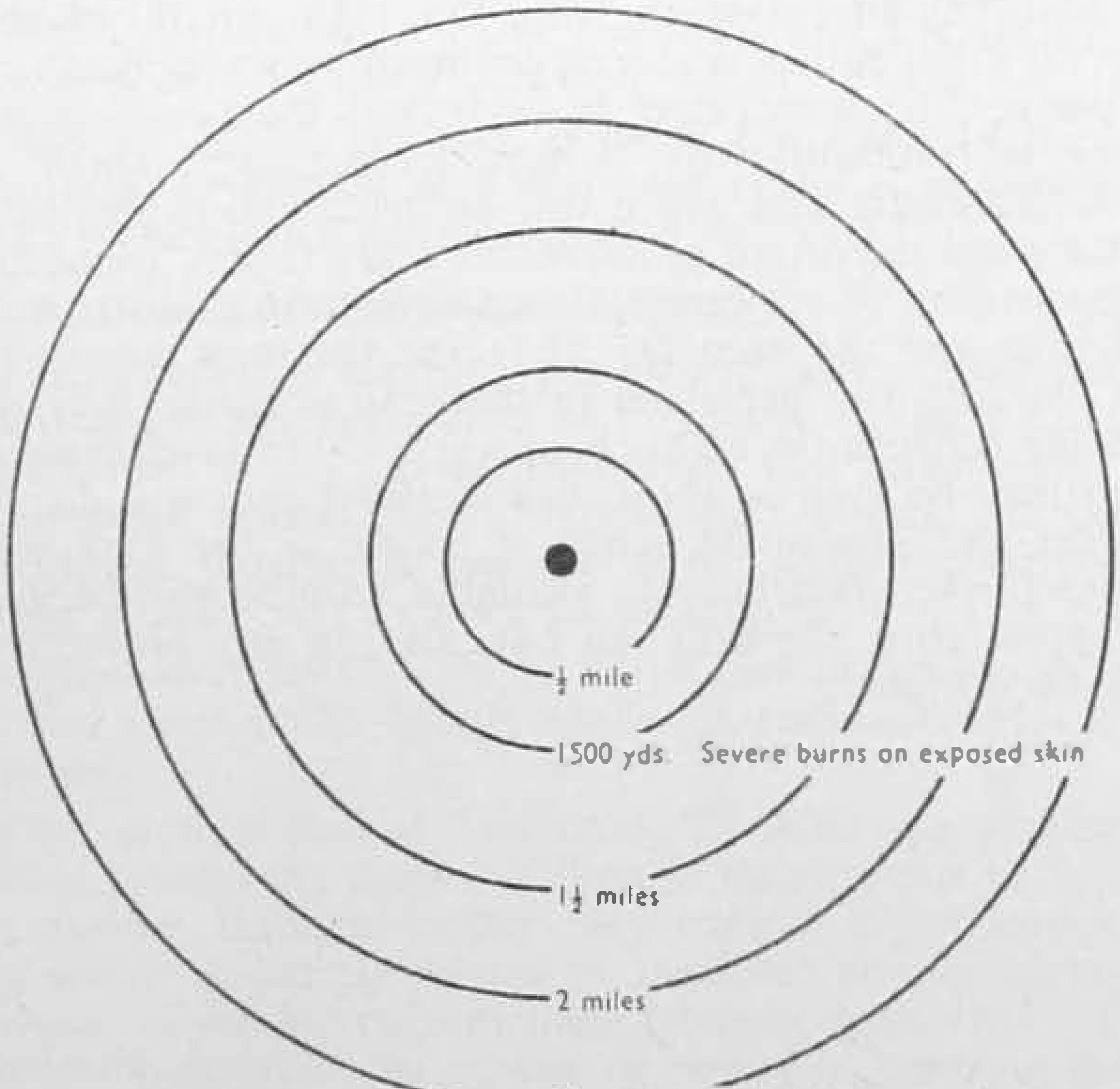

FIG. 3. Radii of Heat Flash.

11. Effects on Material

It is difficult to estimate from experience in Japan the fire danger which might result in Britain. In this country house construction and siting gives rise to a lesser fire risk. Moreover, our Fire Services and equipment are much better. In Hiroshima 4 square miles of the centre of the city were burnt out and in Nagasaki about 1½ square miles. An American estimate for a possible burnout area of one of their cities is about 2 square miles from a considerably more powerful and improved bomb, if such can be produced.

With a low air burst explosion the heat effects would be more intense but concentrated over a much smaller area ; with a ground burst they would be mostly dissipated in the crater area ; and with an underwater burst the heat would be largely absorbed in converting water into steam.

12. Problems of a Fire Storm

In the Hiroshima attack a fire storm was reported though this phenomenon was not experienced in Nagasaki. The production of a fire storm, either by an atomic bomb or a heavy saturation attack by a combination of high explosive and incendiary bombs, is a problem which is being scientifically studied. Nothing was known of this effect of certain methods of bombing until after the war, when it was found to have occurred in Hamburg, and possibly also in several other German cities.

The risk of a fire storm being caused by a high or low air burst atomic bomb must be taken into account, though there will clearly be certain areas which will be much more susceptible to the raising of a fire storm than others. The features of a fire storm are the intense heat caused, together with the high winds which make the task of fire fighting and rescue much more difficult. A fire storm does not, however, start at once, and there will certainly be a number of preventive or mitigating measures which can be instituted beforehand and which will be made known in due course. One of the most important problems to study in this connection will be the recognition of symptoms that a fire storm may be in process of developing and the necessity of taking the most urgent possible steps to evacuate any personnel in the area wherever they may be. The time lag between the actual bombing and the development of the fire storm may be long or short, but in either case will demand the most urgent and immediate action if people in the area are to be saved. As further data become available training will be given not only in appreciating the situation but, also, in any preventive steps that may be devised.

CHAPTER III

RADIOACTIVITY

The effects of radiation in man may be:—

(a) *Immediate :*
the body of gamma rays and neutrons.

(b) *Delayed :* Subsequent to the explosion, through exposure of the person to the radioactive products of atomic fission; or to materials on the target which may have been rendered radioactive by neutrons (induced radioactivity).

Although the entry of the gamma flash into the body is immediate, it must be remembered that the physiological results are delayed.

17. Immediate Effects

The main radiation hazard arises from direct exposure of the person to gamma rays and neutrons at the moment of explosion. Because of their great powers of penetration, however, both these agents may affect, in varying degrees of intensity, people within their range who are protected by buildings from other effects of atomic explosion.

Gamma rays and neutrons do not produce any sensatory reaction, and the victim may not realise at the time the danger that he has incurred.

The onset of the resulting symptoms ("radiation sickness") is early or late according to the dose of radiation received; this will vary with the distance from the explosion and the degree of protection, if any, at the time it occurred.

In high air bursts, however, possibly the whole of the injury can be attributed to gamma rays, since the range of effectiveness of the neutrons is very much more limited.

18. Protection against Immediate Effects

Against attacks by certain types of war gases various other protective devices are available, such as protective clothing and preventive or curative ointments. It is emphasised that measures of this kind have no value against these "immediate" effects, i.e., gamma rays and neutrons, though the position is not quite the same as regards "delayed effects" as is shown in paragraph 20.

It is, however, satisfactory to know that in the design of shelters protection against the lethal results of radioactivity is a practical proposition.

The principle is that of "screening". Although gamma rays are extremely penetrating there is a limit to their powers in this direction. When passing through matter they expend a proportion of their energy which is directly related to the total density of the material penetrated. Even air reduces their intensity somewhat. The denser the screening material the greater its power of reducing the intensity of the gamma rays in a given thickness. For example, building

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materials such as brick and concrete have a greater stopping power than has wood for a given thickness, and lead greater than either on account of its greater density.

The walls of ordinary dwelling houses and surface shelters of last-war type would afford a definite though limited degree of protection, depending upon the distance from the point of explosion. Really thick masonry could remove the danger from gamma rays altogether, even close to ground zero, whilst a moderate thickness of earth affords excellent protection; and only a few feet of earth overhead would afford complete immunity from the effects of gamma rays. The thickness of all ordinary materials which will afford complete immunity from the effects of gamma rays will be notified in due course.

Shelters of the last-war type, such as the Anderson, the surface shelter, tunnels and caves, trench shelters and the like, would provide a very substantial degree of protection, which could be made complete with extra thickening.

19. **Delayed Effects**

Delayed radiation risks are not considered likely to be serious with air burst atomic bombs. If experienced they will be mainly due to the agency of fission products and, more rarely, of induced radioactivity; a remote possibility may arise from the employment by an enemy of certain radioactive by-products.

Fission Products: As stated in Chapter I it is unlikely that fission products in high concentration will be found on a target area unless the explosion has occurred at a low height, underground, or underwater in close proximity to the target. Under these conditions the initial contamination may present such a serious hazard that the affected area may have to be evacuated for some time. On the other hand, any area experiencing heavy contamination from a low air burst bomb will almost certainly be completely pulverised by blast and unless there were people trapped in shelters in this area there might be no immediate need for any Civil Defence or other personnel to enter it.

Apart from their external radiation effects, fission products are dangerous if they gain entrance into the body by inhalation, by contamination of broken skin, or through contaminated food or drink ("radioactive poisoning").

Induced Radioactivity: In a low air burst, many elements and their compounds in materials in the central zone may be rendered artificially radioactive through bombardment by neutrons released by the explosion.

Although the intensity of induced radioactivity may rapidly wane, prolonged exposure of the body to the radiations evolved may constitute a definite hazard to man.

Radioactive by-products: In the manufacture of fissile elements and in the operation of atomic piles, certain highly radioactive materials of varying half-lives are produced which may, theoretically, be used in war in the form of radioactive dusts or clouds. The quantities so produced, however, are not likely to be so great as to create a serious menace; moreover, their progressive decline in activity, coupled with difficulties in storage, carriage, handling and loading, make their possible employment in war still more problematical.

20. **Protection against Delayed Effects**

There are six principles of protection against the effects of delayed radioactivity. They are:—

(i) Detection (Radiation Metering).
(ii) Suitable Clothing and Equipment.
(iii) Avoidance of Heavily Contaminated Areas.
(iv) Personal Cleansing.
(v) Decontamination.
(vi) Periodical Medical Examination and Rules Governing Exposure.

(i) *Detection (Radiation Metering)*

Means of immediate detection of the presence of radioactivity already exist in the shape of radiation meters. These are instruments which record the total radiation dose received at the spot where the instrument is, or, in some cases, the rate at which that dose is being received. Since gamma rays travel quite long distances in air, these instruments average up the effects of fission products from a considerable area, just as the body would do. Other instruments, in their turn, will indicate the slightest trace of radioactive contamination on clothing or skin, resulting from dust or water contaminated by fission products. These meters will be more fully discussed later in this chapter. In this connection, however, it is important to remember that gamma rays of themselves are incapable of contaminating anything, or of rendering any material radioactive.* Gamma rays depend, for their effects, entirely on causing casualties from radiation sickness.

Although scientific knowledge is not needed in the use of meters, a certain amount of training is necessary and will be given to selected individuals. Ability to manipulate and read instruments is not in itself enough. Training is needed in the interpretation of the readings taken.

Three types of meter have been recommended for use in the Civil Defence Corps and ancillary Services. They are as follows :—

(*a*) Individual Dosimeter.
(*b*) Portable Dose-rate Meter.
(*c*) Contamination Meter.

Individual Dosimeter: This is a small instrument which can be easily carried on the person. The type at present recommended for Civil Defence is known as the Quartz-Fibre Electroscope. It is about the size of, and similar in appearance to, a fountain pen, and has a clip by which it can be fastened in the breast pocket ; other types are under development.

The total dose is recorded and the wearer can from time to time take a reading, and thus keep a constant check upon his own safety. The reading is taken by applying one end of the instrument to the eye and reading the dose on the scale which will be visible against the light. (See Fig. 4.)

Portable Dose-Rate Meter: There is an important difference between this type of instrument and that just described, in that instead of reading the total dose which has accumulated up to the

* Scientists can detect slight activity following bombardment by gamma rays, but it is of no significance for the present purpose.

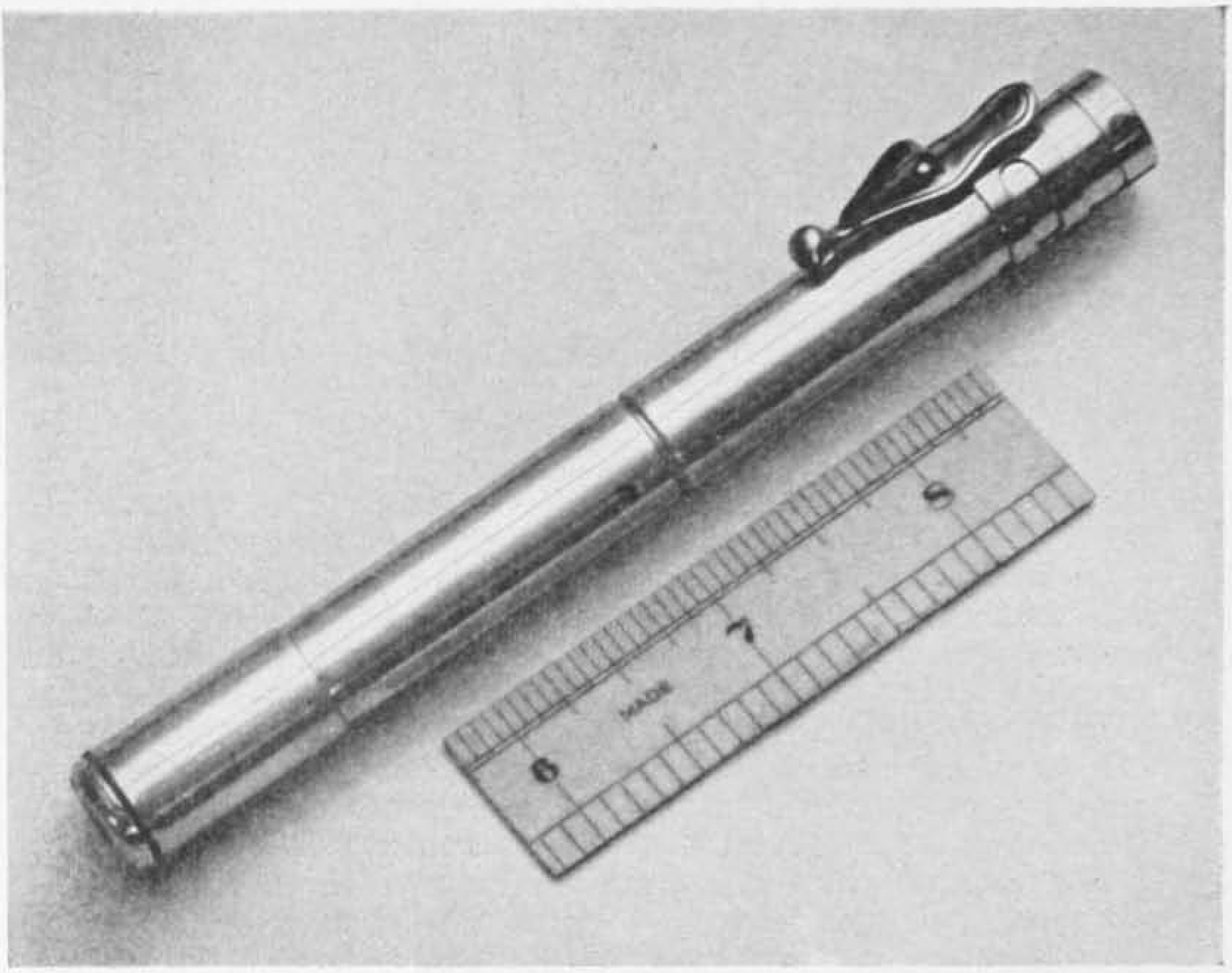


FIG. 4. Individual Dosimeter

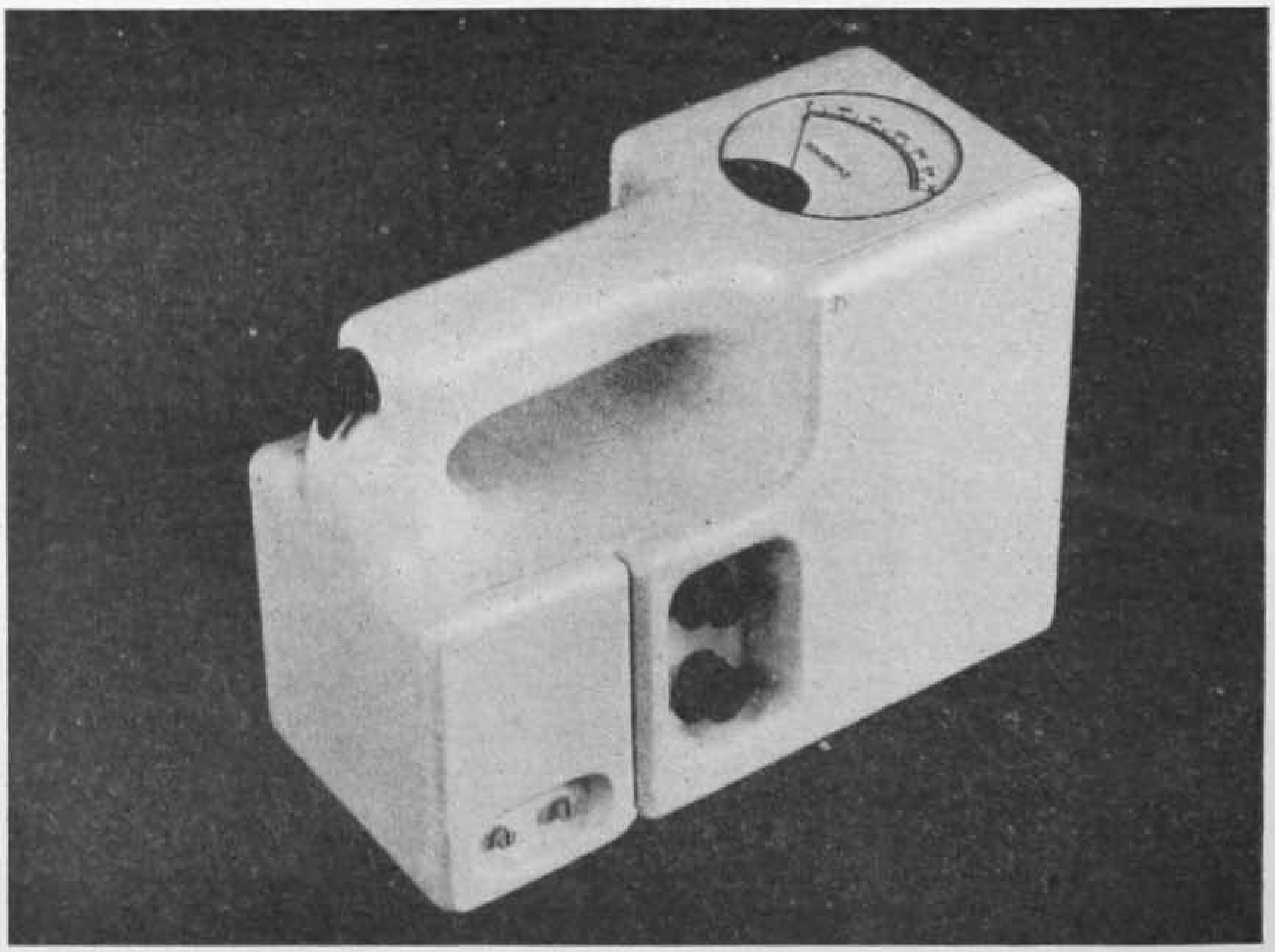
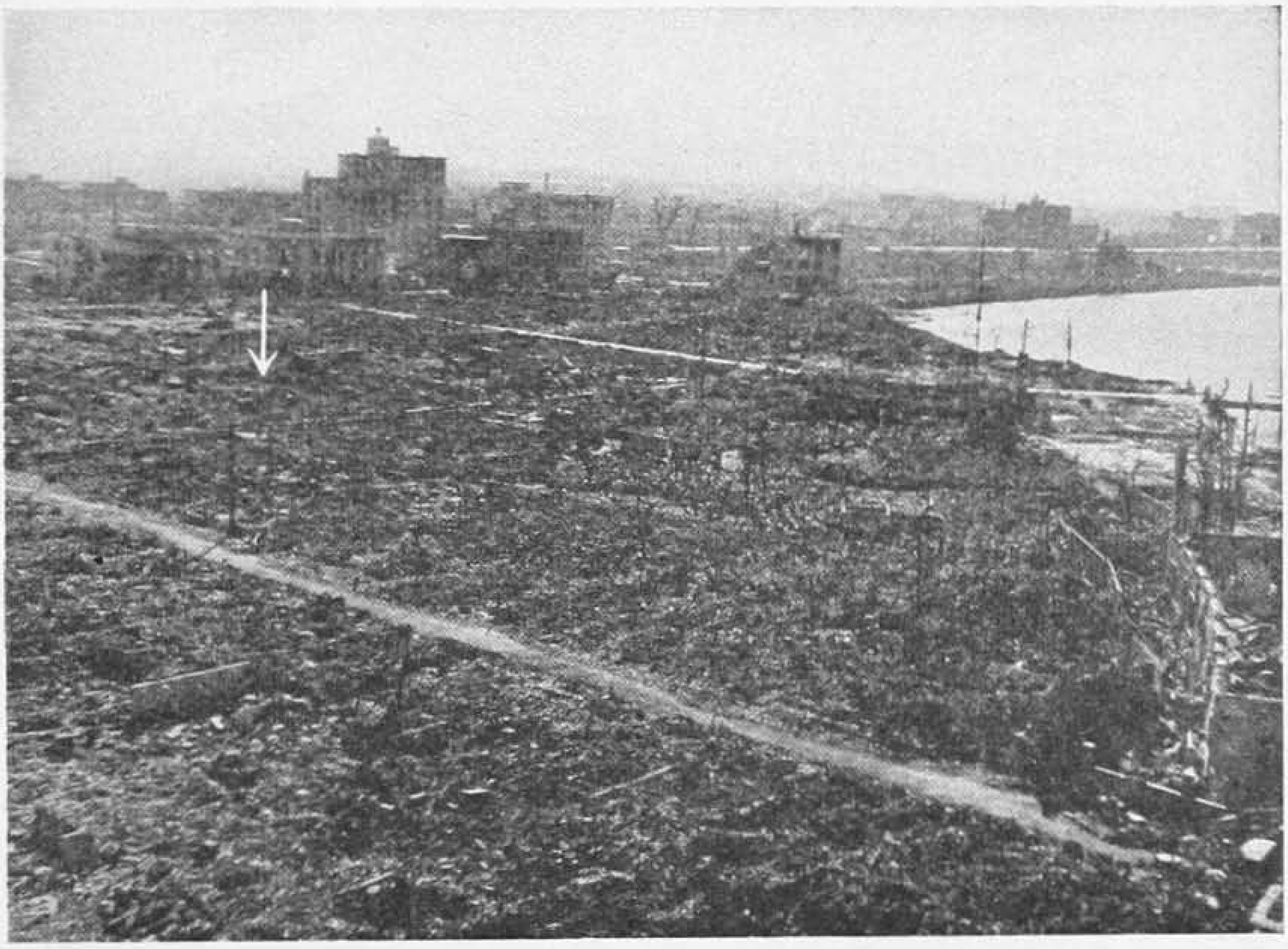


FIG. 5. Portable Dose-Rate Meter



Photos Nos. 1 and 2. HIROSHIMA. General views looking across the centre of damage, the approximate position of which is marked with an arrow. It will be seen that some of the framed buildings quite near the centre remained standing. The tall building in Photo No. 1 is the same as that seen in Photo No. 7. The foreground illustrates the remnants of Japanese dwellings, razed to the ground.

Photo No. 3. N A G A S A K I. A general view of the area near the centre of damage, which is to the left in the picture, only 300 yds. away from the bridge. Note the little that remains (in the foreground) of blasted and burnt Japanese dwellings. For a view of such houses, undamaged, see Photo No. 19.

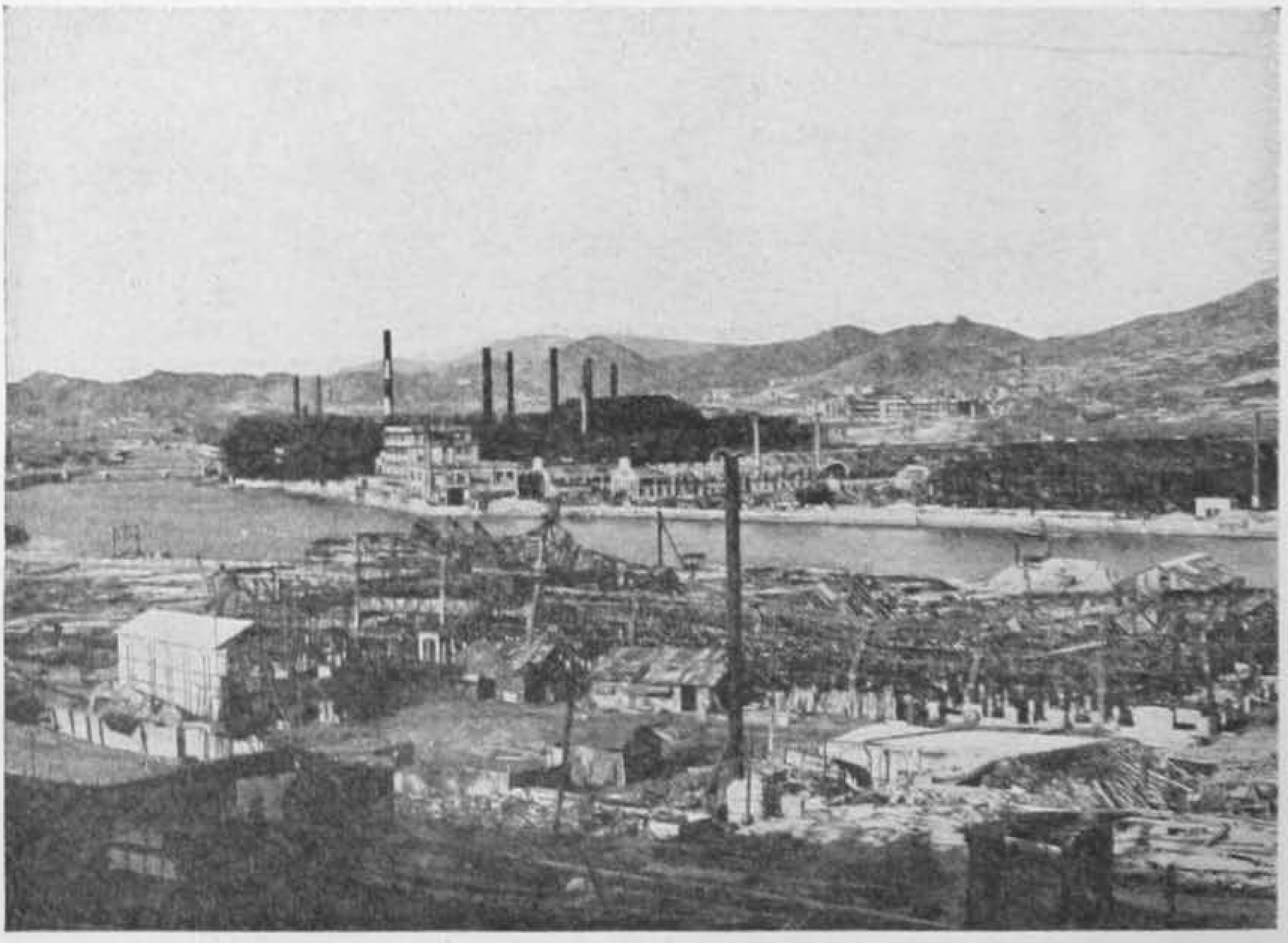


Photo No.4. N A G A S A K I. A general view showing some of the industrial buildings. That in the foreground was a gutted woodworking plant, just over a mile from the centre of damage, which was beyond the group of chimneys of the Mitsubishi Steel Works, seen in the middle distance.

Photo No. 5. N A G A S A K I . Reinforced concrete school with a timber roof, 500 yds. from the centre of damage, which is to the right of the photograph. The upper part of the long wall further from the explosion has been bent over, partly by a thrust through the roof from the other long wall and partly by wind suction. This is a typical case of " mass distortion."

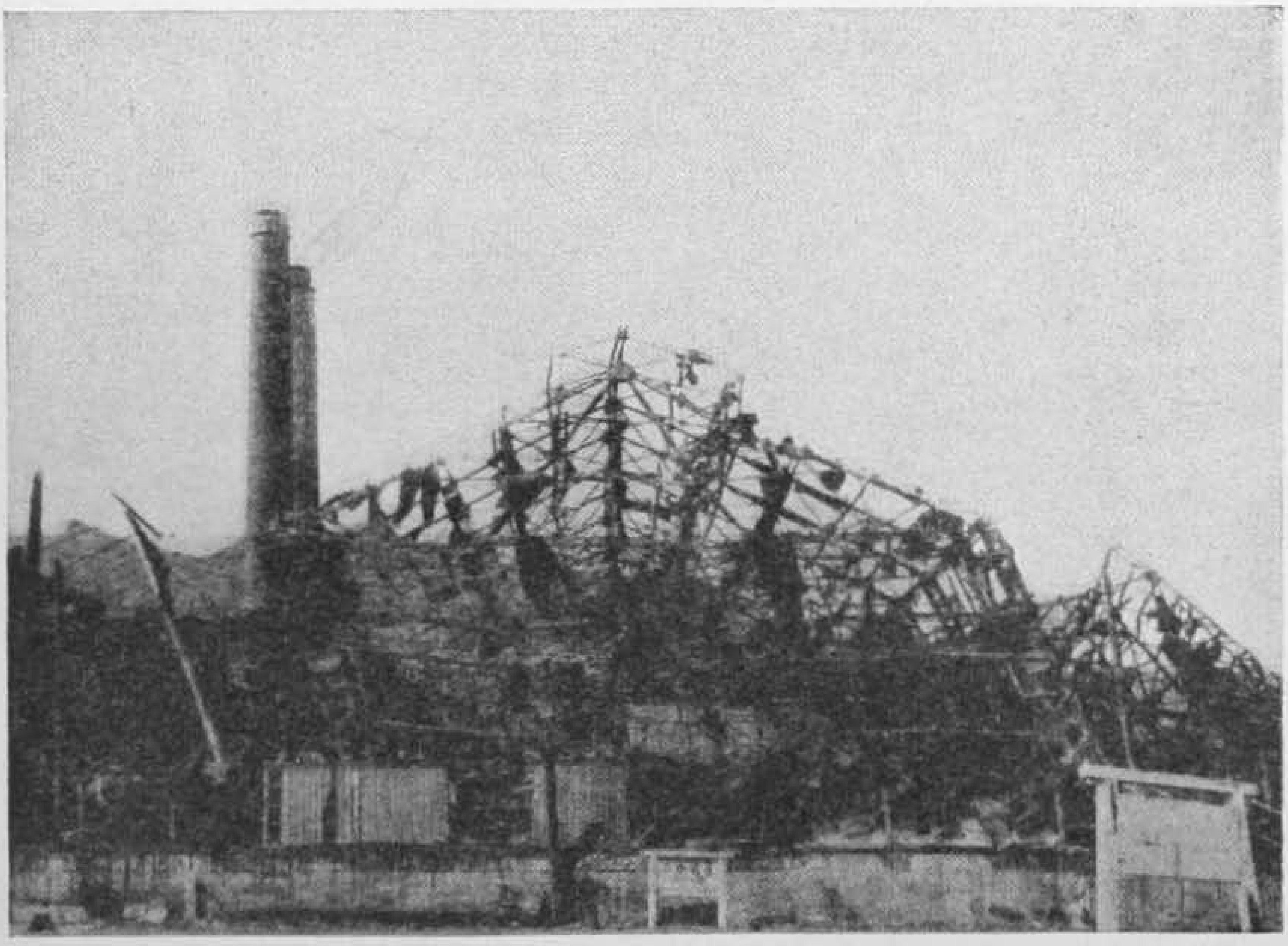


Photo No. 6. N A G A S A K I . Mass distortion of steel framed shed buildings about half a mile from the centre of damage, which was to the right of the buildings in the photograph. It will be seen that the entire main frame is seriously distorted away from the explosion.

Photo No. 7. HIROSHIMA. Reinforced concrete building about 300 yds. from the centre of damage, which is to the left of the photograph. There was no serious structural damage, although a roof panel was depressed and some internal party walls were deflected. Designed for earthquake resistance, this building has a composite reinforced concrete and steel frame.

Photo No. 8. HIROSHIMA. Reinforced concrete building 200 yds. from the centre of damage, which is to the right. The blast from the bomb forced the roof slab down, the slab shearing round the column heads, leaving the internal columns projecting through the debris. Few concrete buildings failed in this way.

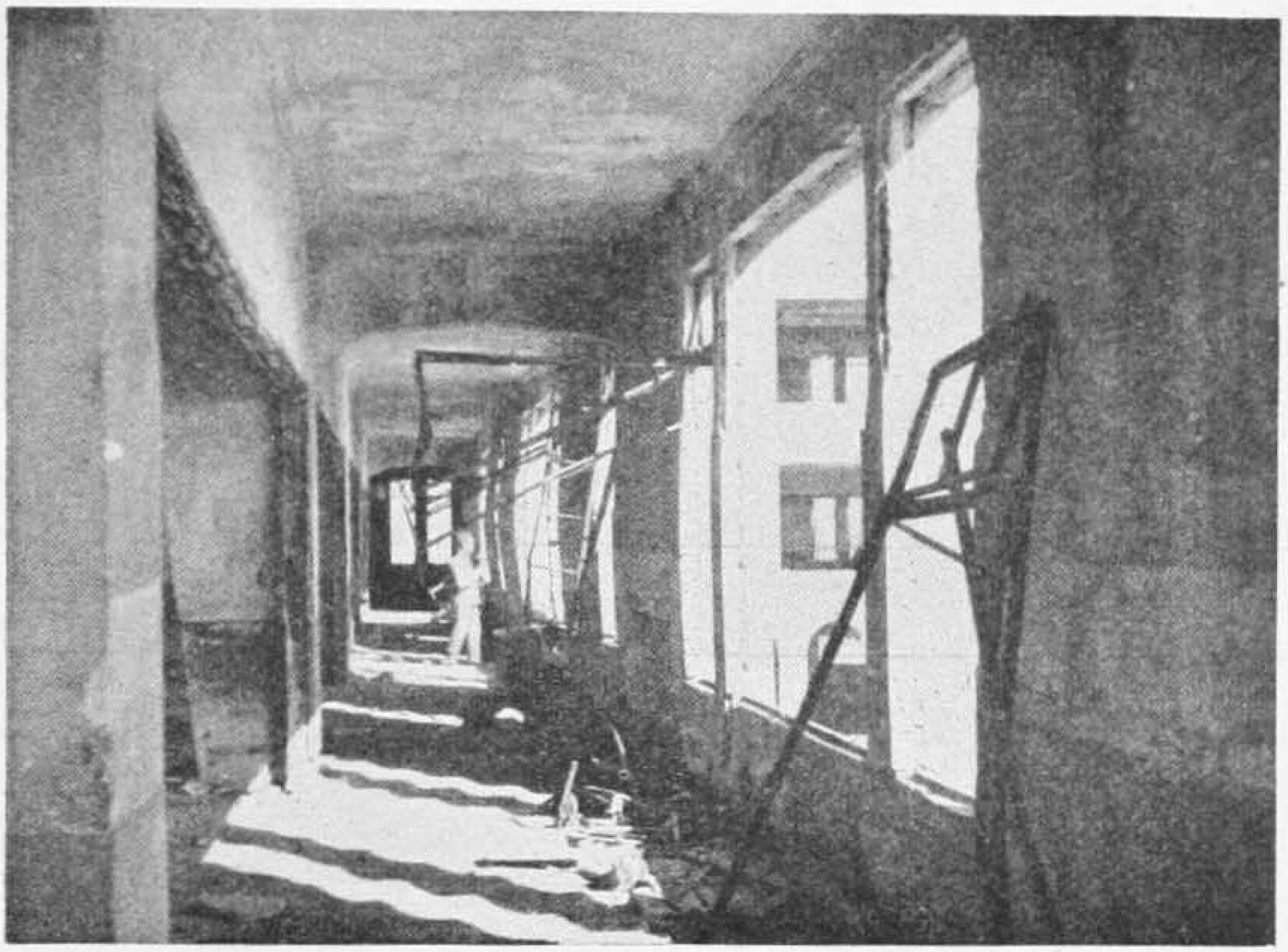


Photo No. 9. H I R O S H I M A . Reinforced concrete school 500 yds. from the centre of damage, which is to the right. The frame of this building was of special design (portal) and resisted the lateral forces. The outside walls were of continuous reinforced concrete, and although they were deflected, as seen, they did not fail.

Photo No. 10. N A G A S A K I . Reinforced concrete single storey factory rather less than a mile from the centre of damage, which is to the right. The arched reinforced concrete roof failed, the side nearer the explosion being forced inwards and the far side forced upwards.

Photo No. 11. H I R O S H I M A . Small steel framed shed ¼ mile from the centre of damage, showing the distortion of the entire framework, with the building leaning away from the explosion.

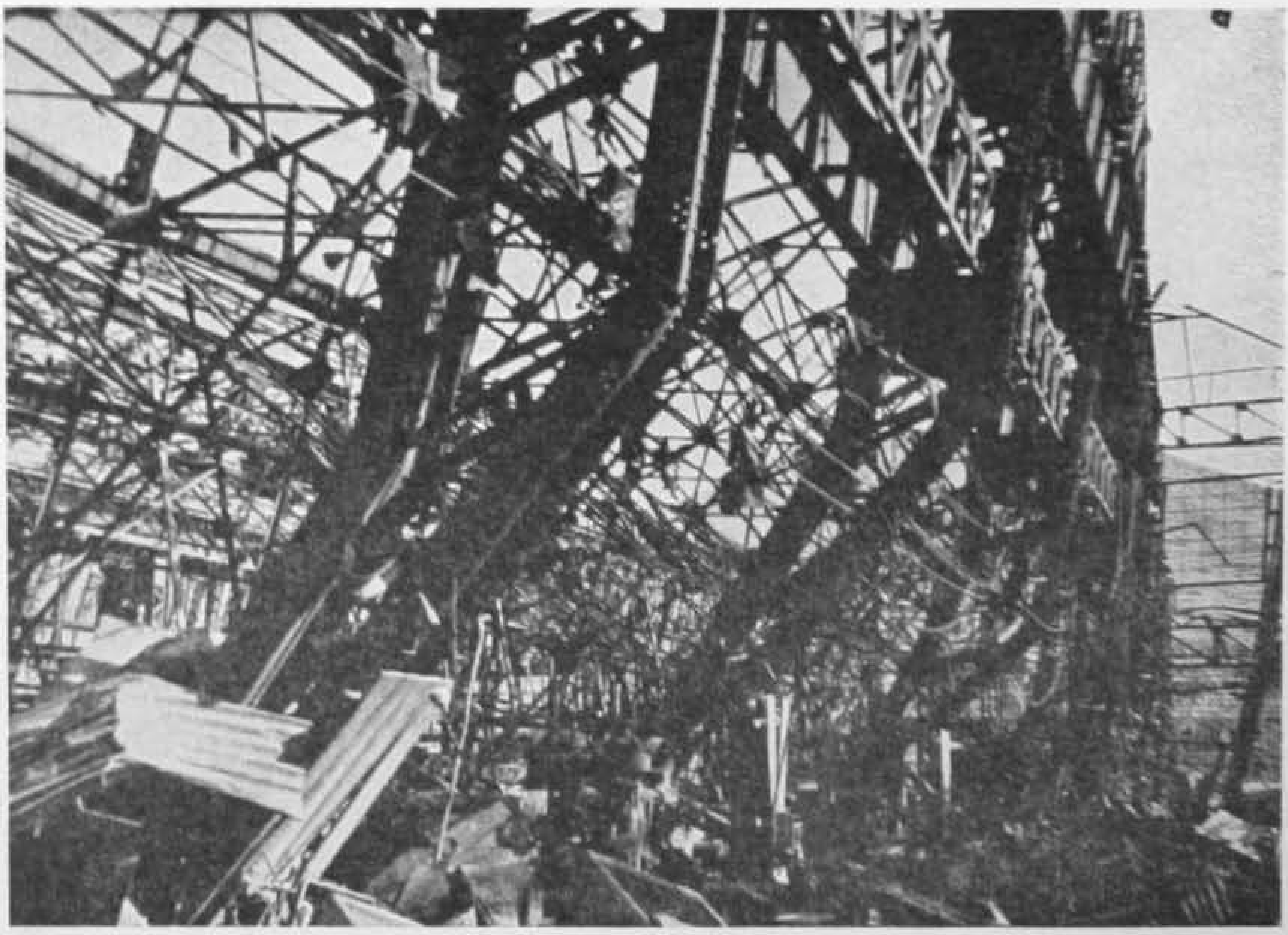


Photo No. 12. N A G A S A K I . Large steel framed shed in the Mitsubishi Steel Works, ¾ mile from the centre of damage. The steel stanchions have been bent (away from the explosion) and the roof trusses on both sides of these stanchions have collapsed.

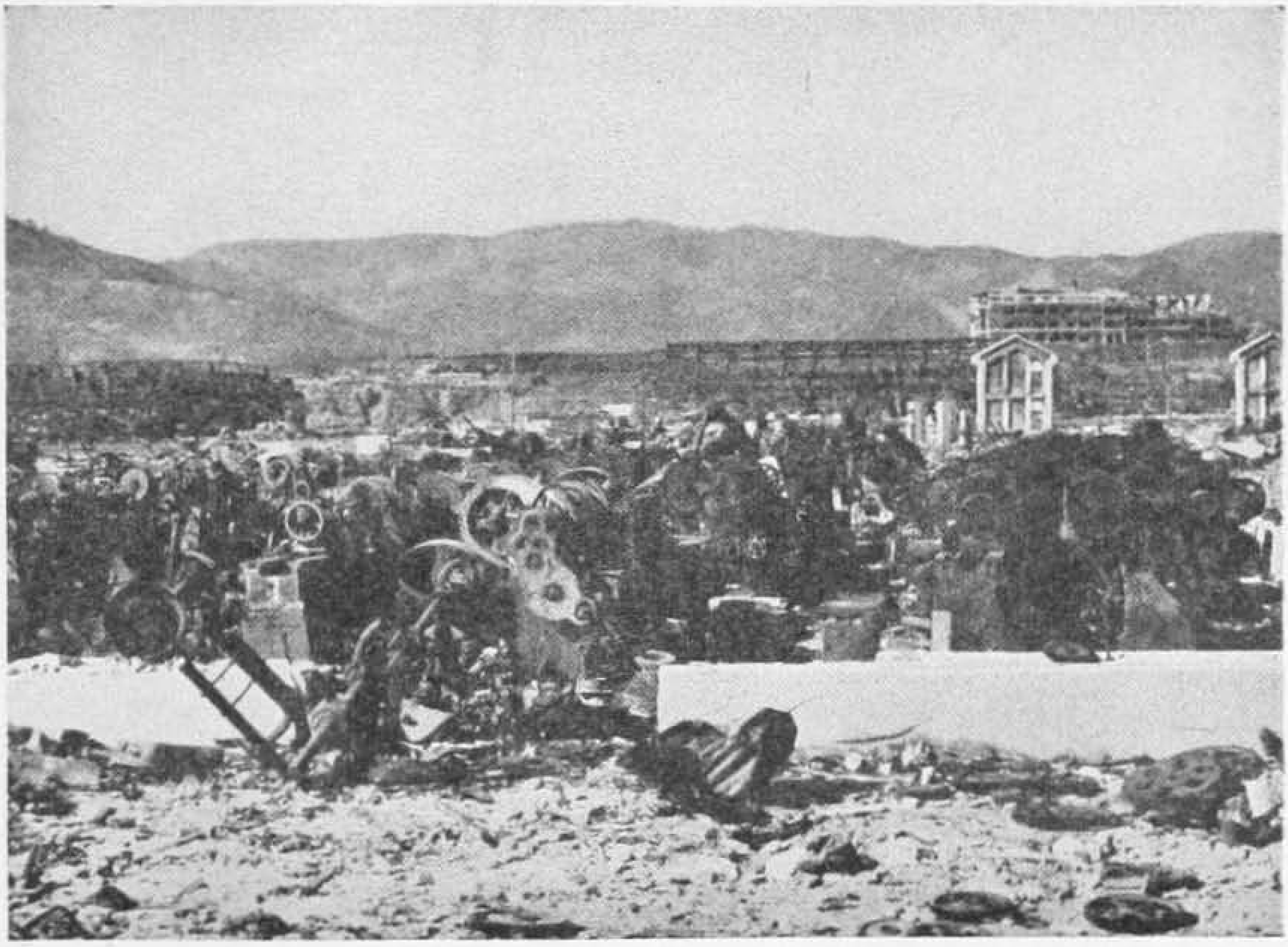


Photo No. 13. NAGASAKI. ½ mile from centre of damage. Typical damaged machines in one of the many timber workshops destroyed by blast and fire. Some machines were overturned by movement of the buildings, some destroyed by fire alone; others damaged by exposure to the weather.

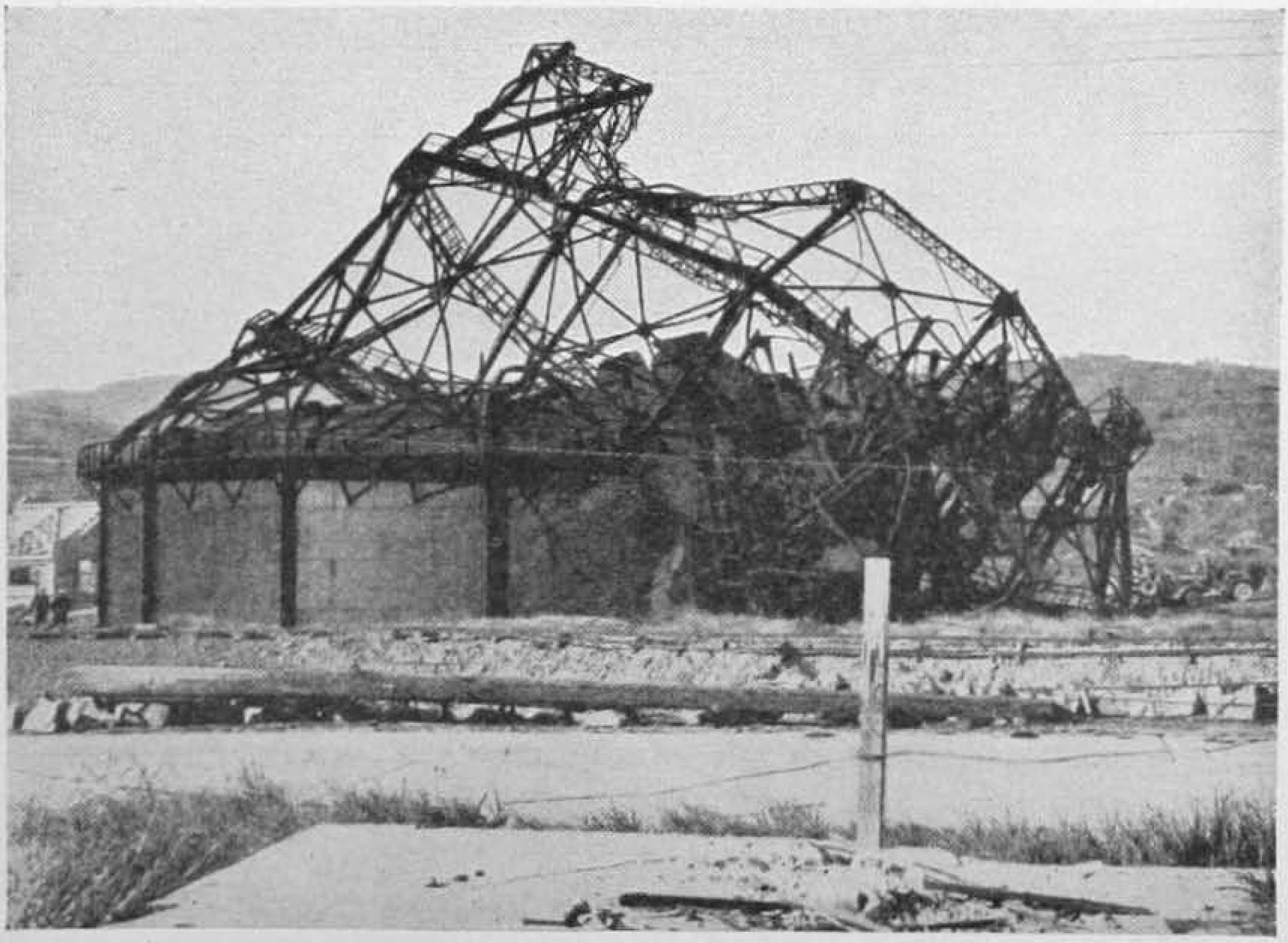


Photo No. 14. NAGASAKI. Blast effect on a gasholder ½ mile from centre of damage. Note the way in which the whole framework has been bent away from the explosion.

Photo No. 15. HIROSHIMA. Three storey bank building with load bearing brick walls of strong construction and comparable with British standards. This degree of damage to such buildings extends to a radius of ½ mile from centre of damage. Compare with the behaviour of the reinforced concrete framed building in the background.

Photo No. 16. NAGASAKI. The Roman Catholic Cathedral 600 yds. from centre of damage. The walls were of heavy load-bearing brick construction. Most of the damage is attributable to blast, although fire subsequently consumed all combustible debris. Note in the foreground the huts erected by the Japanese for temporary living quarters after the atomic bomb raid.

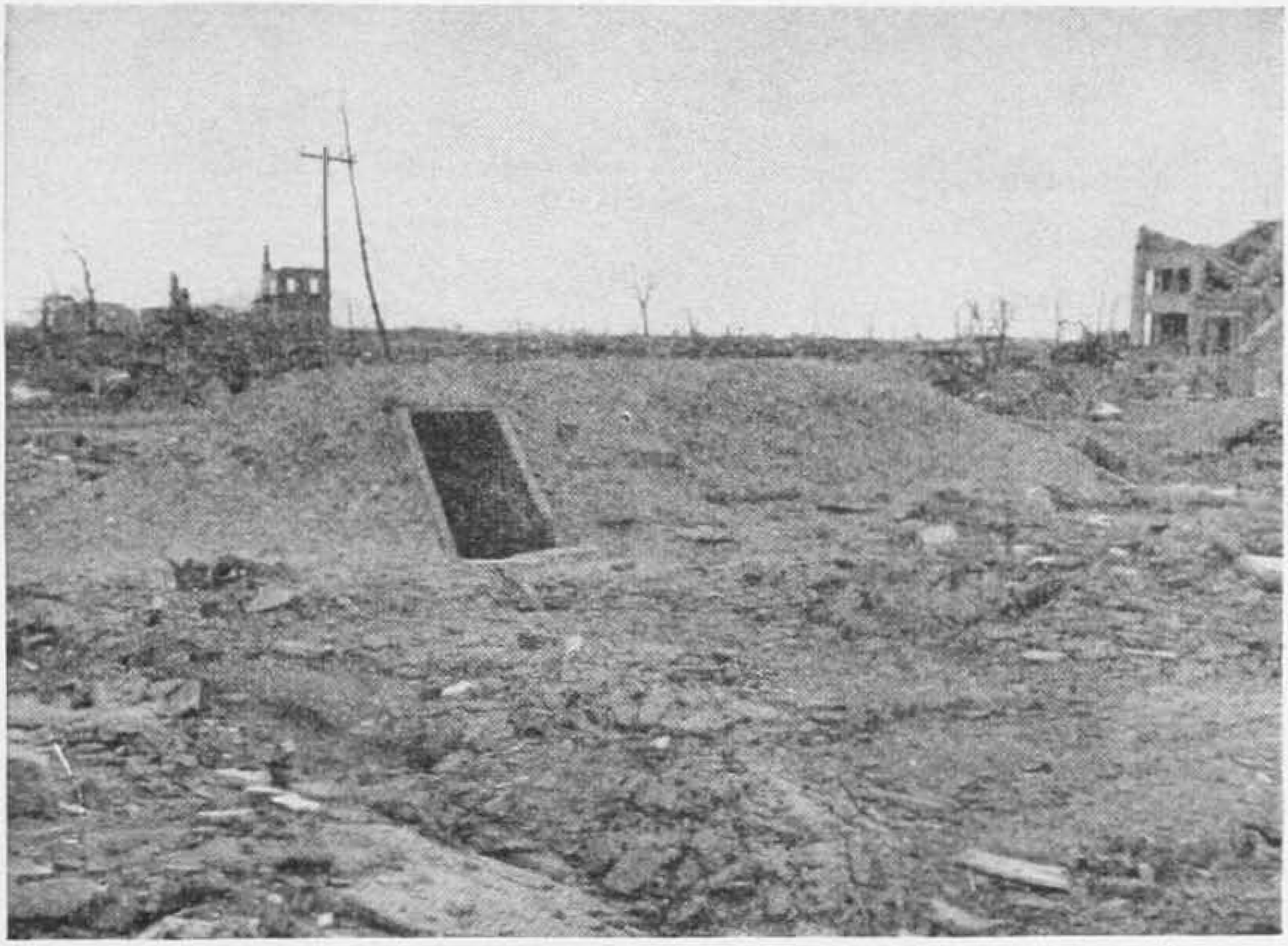


Photo No. 17. HIROSHIMA. Typical, part below ground, earth-covered, timber framed shelter 300 yds. from the centre of damage, which is to the right. In common with similar but fully sunk shelters, none appeared to have been structurally damaged by the blast. Exposed woodwork was liable to "flashburn." Internal blast probably threw the occupants about, and gamma rays may have caused casualties.

Photo No. 18. NAGASAKI. Typical small earth-covered back yard shelter with crude wooden frame, less than 100 yds. from the centre of damage, which is to the right. There was a large number of such shelters, but whereas nearly all those as close as this one had their roofs forced in, only half were damaged at 300 yds., and practically none at half a mile from the centre of damage.

Photo No. 19. NAGASAKI. Typical Japanese houses in a street screened from damage by the surrounding hills. Buildings of similar construction formed the main proportion of buildings in Nagasaki and Hiroshima.

Photo No. 20. NAGASAKI. A room in the concrete hospital, ½ mile from the centre of damage. The building was structurally undamaged, and one of the few of its type to escape internal fire damage. The collapse of suspended ceilings, partitions, etc., caused many casualties; fire would have increased their plight.

Photo No. 21. HIROSHIMA. Roughening of polished granite by " flash " heat effect at 200 yds. from the centre of damage. The polish remains only where shielded by (*a*) a man seated on the steps, (*b*) a man leaning against the corner of the plinth adjoining the steps and (*c*) in the " shadows " of the plinth mouldings.

Photo No. 22. NAGASAKI. Timber framing scorched by heat radiation at $\frac{3}{8}$ mile from the centre of damage. The surface is unscorched where it is shielded by the uprights.

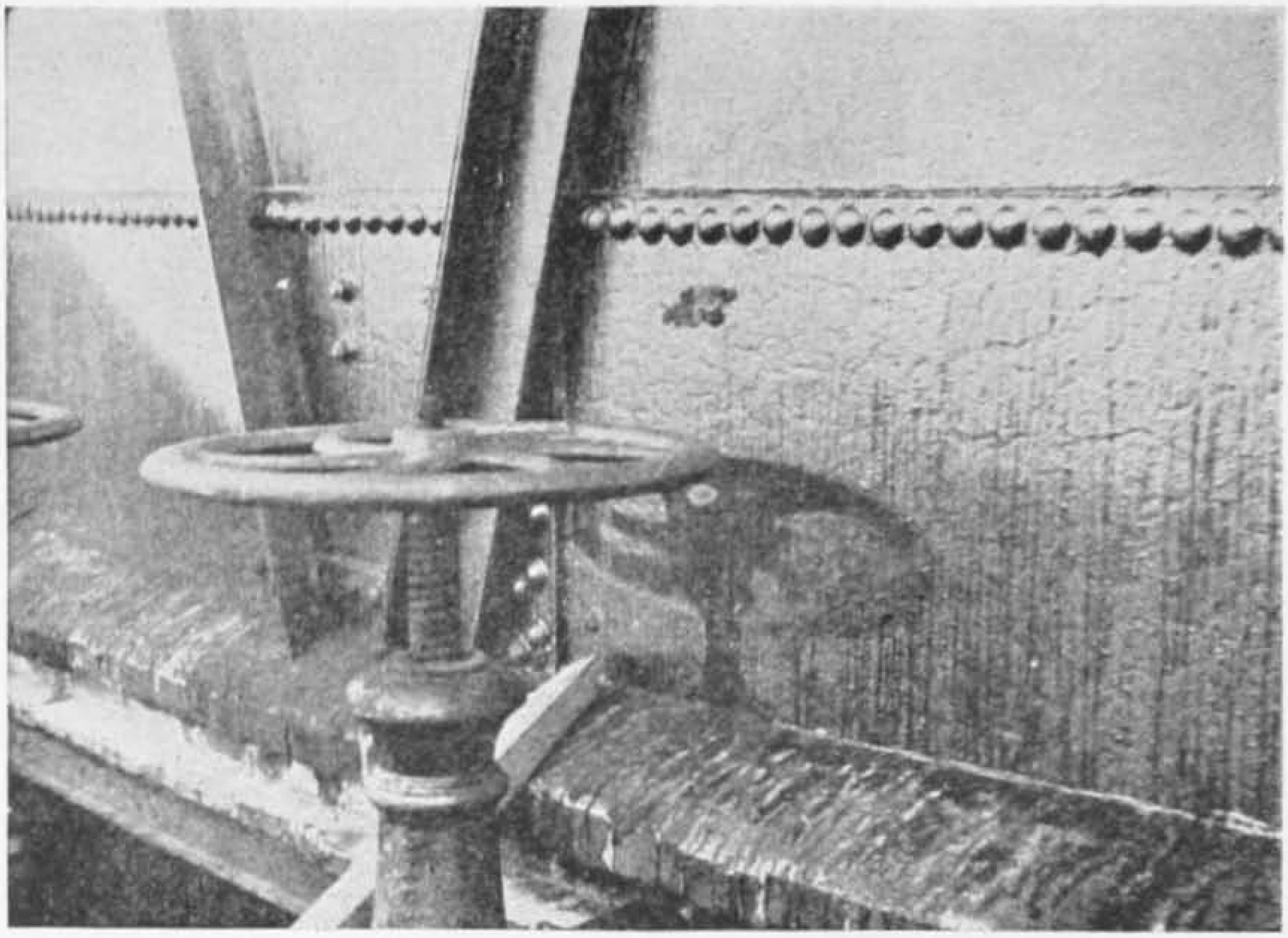


Photo No. 23. HIROSHIMA. Shadow cast by valve-wheel on side of gasholder $1\frac{1}{4}$ miles from the centre of damage. The bituminous coating on the steel plates was affected by heat radiation except where shielded by the wheel and spindle.

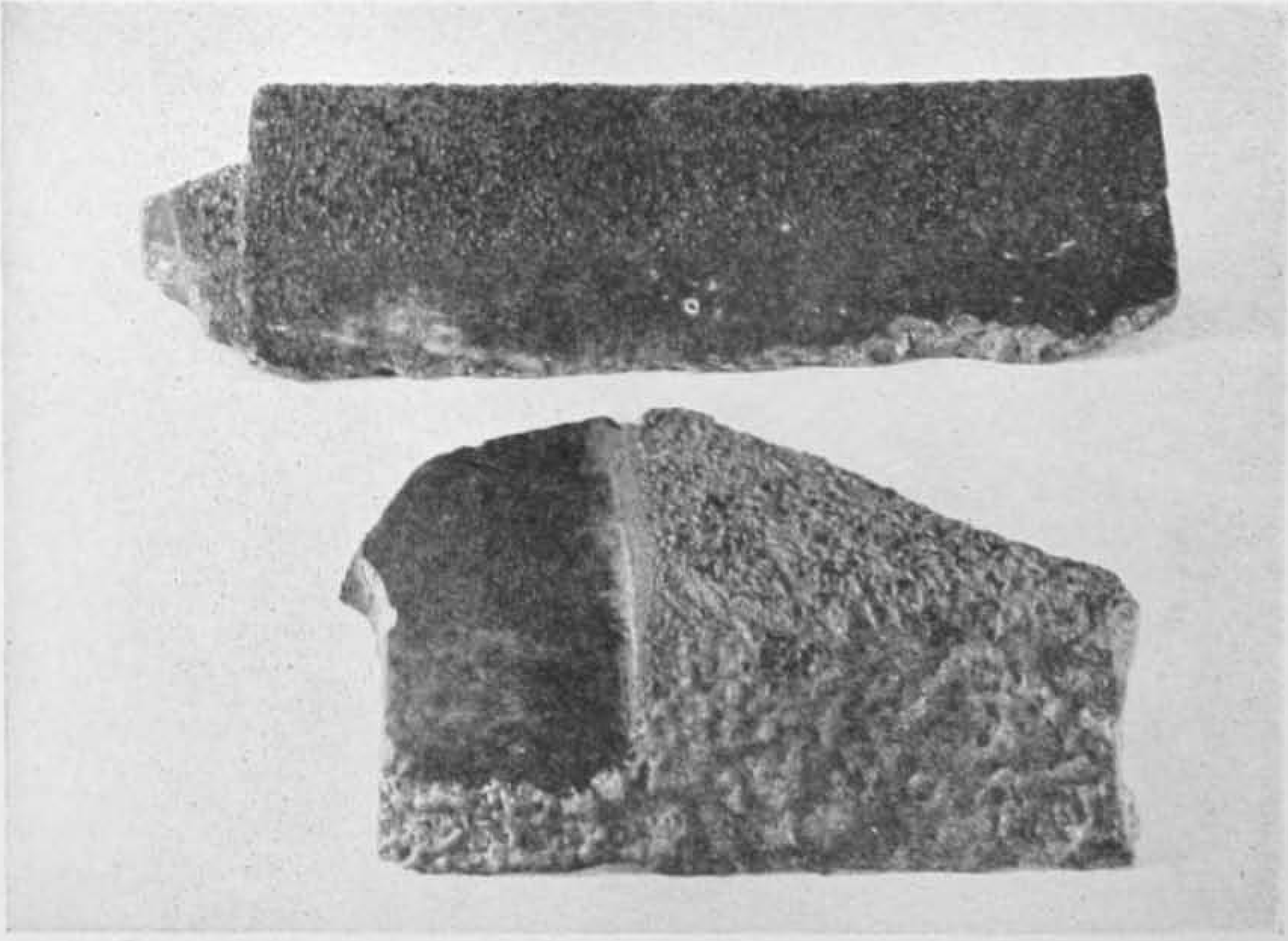


Photo. No. 24. NAGASAKI. Section of ridge tile and part of pantile recovered from the centre of damage, showing the " bubbling " effect produced by the intense heat radiation. Note the gradations on the half round tile; also the unscorched section of the pantile where the tile has been protected by the overlap of the adjacent tile.

moment, they measure the rate at which that dose is being received per hour. Portable meters are battery-operated and are likely to be supplied for Civil Defence use in a stout, felt-lined case with a shoulder sling. A dial reading can be taken at any time by turning a switch. (See Fig. 5.)

These meters are for measuring dose rate contours around the heavily contaminated central zone at ground zero, so that safe working times can be calculated from previously prepared tables. The process is analogous to the use of the pocket vapour and ground detectors for blister gas.

Contamination Meter: This is a very sensitive instrument for the purpose of detecting any trace of radioactive contamination on the skin or clothing of individuals.

Contamination meters are for installation in hospitals, cleansing stations, and other places where personal cleansing is necessary. By walking past the instrument it is possible to tell whether an individual is contaminated or not, as the increasing meter reading and rising stridency of the incorporated loud-speaker will give immediate evidence of the fact. The contaminated can thus be segregated from the uncontaminated, and the former recalled and subjected to a detailed " frisking " by going over them with the probe of the instrument held close to but not touching their skin and clothing. This will indicate with accuracy the exact location and area of the contamination. (See Fig. 6.)

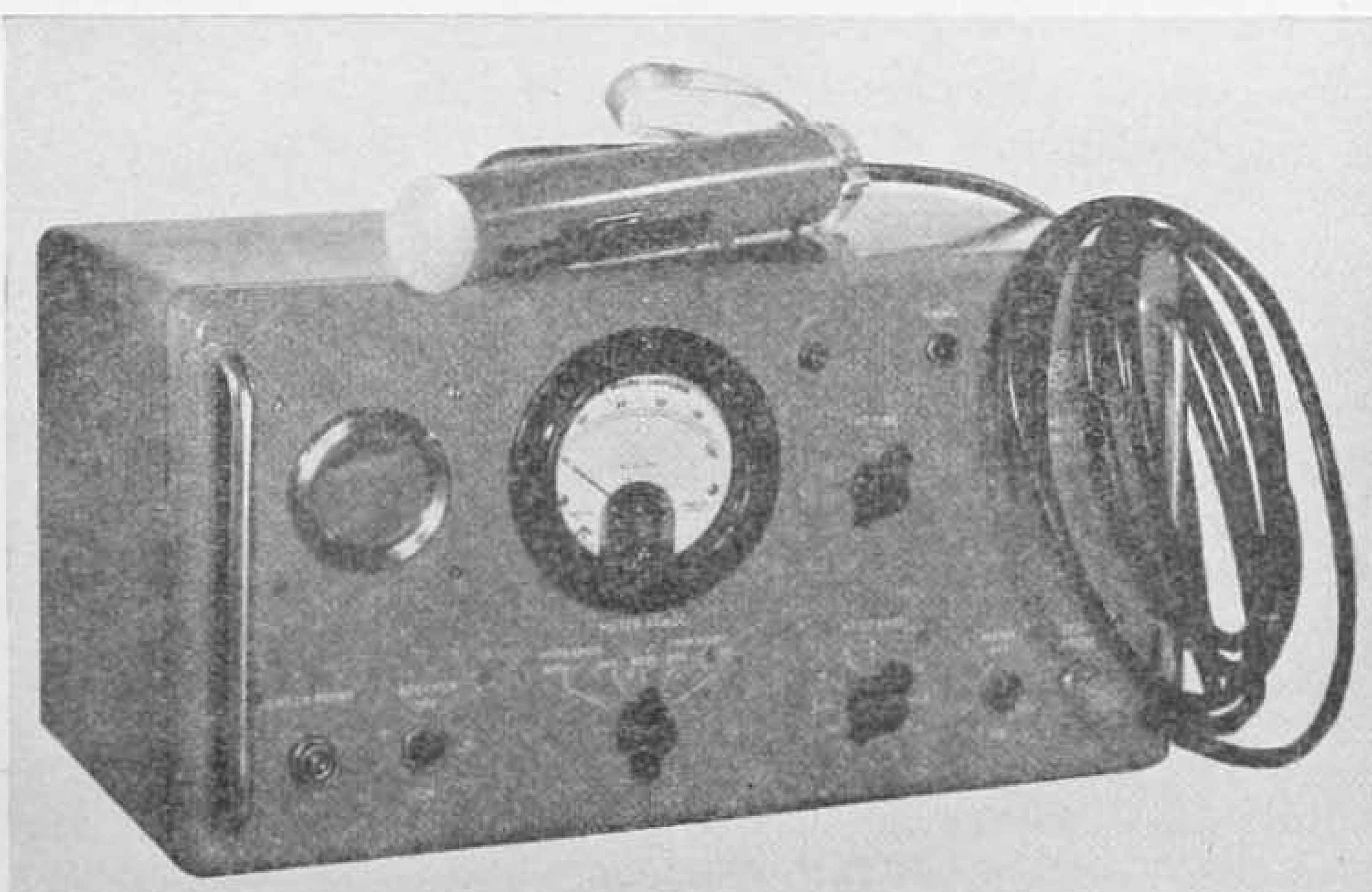


FIG. 6. Contamination Meter.

(ii) *Clothing and Equipment:* Though no form of clothing exists which will protect the wearer against gamma flash, or the gamma rays emanating from fission products and from materials in which radioactivity has been induced, it is quite easy to protect the individual from the alpha and beta particles which are likely to be given off, since they have both a very short range and practically no powers of penetration, as explained in the following paragraphs.

Alpha particles have an extreme range of only a couple of inches in air, and have no powers of penetration. The danger lies in the possibility of their being emitted by material which has been inhaled, or swallowed, or absorbed into the body through broken skin (e.g., wounds). The likelihood of exposure of this sort is regarded as small.

Beta particles have a range of several yards in air, and poor powers of penetration. Like the alpha particles they are extremely dangerous if they are emitted by material which has gained access to the interior of the body and, in addition, they can cause severe skin injuries if contact of such material with the bare skin is prolonged. Any ordinary clothing of reasonably close weave suffices to keep beta active material from contact with the skin, provided that openings at wrist and ankle can be kept closed in one way or another. The wearing of the respirator will protect against inhalation or swallowing.

It will, also, be necessary to keep contaminated dust, and the like, out of the hair. This can be done by any suitable type of hood or cap, nor need the latter be non-porous.

From the foregoing emerges a picture of suitable clothing and equipment for those who have to pass through or work in a heavily contaminated area, namely :—

(*a*) Respirator.

(*b*) Denim Overalls (example).

(*c*) Gloves (preferably of rubber or fabric).

(*d*) Gumboots or strong leather boots as used in the Rescue Section.

(iii) *Avoidance of Heavily Contaminated Areas:* It should be a rule that no person is allowed to enter or remain in a heavily contaminated area unless his duty compels him to do so. Members of the public normally need to be evacuated in a planned and orderly manner. Reconnaissance personnel with their meters will know the extent of the area, and their advice must be followed.

Certain precautions must be enforced in the case of persons who have to stay and work in the area. No food, drink, sweets, smoking materials, etc., must be carried, owing to the danger of their contamination by fission products. If the work in the area is going to take longer than an hour or two it will be necessary to provide food and drink. This could be done by mobile canteens bringing the necessary supplies from outside to the upwind perimeter of the area, in airtight containers, and allowing no persons to partake until their hands have been thoroughly washed and scrubbed (particular attention being paid to the parts under the nails). Nor, once gloves have been removed, must the hands be allowed to touch clothing or equipment.

(iv) *Personal Cleansing :* There are numbers of protective measures common to both atomic and chemical warfare. The arrangements for cleansing contaminated personnel are an example, and an almost identical procedure will serve those contaminated by fission products as well as those contaminated by chemical warfare agents.

It has been stated earlier in this chapter that there is no need to make use of non-porous protective clothing, unless chemical warfare agents are also present in the radioactive area. None the less care will be needed in undressing so as to prevent the spread and inhalation of radio-contaminated dust. During the process of undressing care must be taken not to shake particles of clothing as they are removed, since this would tend to make dust particles fly, and so spread the contamination. A light spraying with water is definitely valuable and should be the rule. Each article when removed must be placed in an ordinary bin to await disposal or decontamination.

Washing procedure will have to be very thorough, use being made of scrubbing brushes ; and it will be of advantage if hand-basins and nail brushes can also be provided, since the angle of skin and nail needs careful attention. After washing, the person should again be metered. If contamination still remains the washing will have to be repeated until the meter records a negative result.

(v) *Decontamination :* It is important to realise that radioactivity, unlike chemical warfare agents, cannot be destroyed. It can be removed and taken to a place where it can do no harm, or it can be left to decay by natural means, which in some cases is a very long process and in others relatively short. There is at present no other method of decontamination suitable for use in Civil Defence.

(a) *Clothing :* If clothing is badly contaminated it will probably be better to dispose of it altogether. More lightly contaminated clothing can be rendered safe by more or less normal laundry methods, or by dry cleaning.

(b) *Other Materials :* If decontamination can be taken in hand before the contamination has had time to be absorbed into the material, removal by methods similar to those used for removal of persistent gas contamination can be undertaken.

(c) *Streets and Public Places :* There is at present no known method of achieving complete decontamination, though hosing down will certainly help to aid dispersion provided it can be done without creating a further hazard with the water thus used: i.e., the disposal of such water must he carefully watched. If conditions permit the area can be left to the process of natural radioactive decay.

(d) *Food :* Gamma rays have no harmful effects upon foodstuffs. Foods which were within very close range of neutrons when the bomb exploded are likely to be irradiated and would have to be disposed of irrespective of whether they were in airtight containers or not. The depositing of fission products upon unprotected foodstuffs constitutes the greatest danger, which would be obviated by storing of food in airtight containers.

(vi) *Periodical Medical Examination and Rules Governing Exposure :* It will be necessary to keep a careful check upon the health of Civil Defence personnel whose work carries them into radioactive areas. Meters of one kind or another will indicate the amount of dose received on any one occasion and will warn the individual when it is no longer safe to expose him or herself.

Linked with this problem is that of the dose which may not be exceeded. This maximum permissible dose is now under active investigation and will be notified in due course. It depends to some extent on the time over which it is accumulated. It can be said now, however, that there will have to be a number of different scales laid down to meet the varying conditions of operations. For example, there will be a scale required for the general public, another scale for Civil Defence Corps personnel and the personnel of associated Services such as the Police and the Fire, and a further scale for special emergency work such as the rescue of trapped shelter occupants. These scales, when finally decided, must be known to all holding positions of responsibility so that they can take operational decisions, and also to those concerned with medical and first aid work. The general object will be to ensure, as far as practical, that exposure is under careful control, and if exceptional risks have to be taken at least they will not be ordered blindfold.

A radioactive dose is measured in units known as roentgens. Radiation meters for Civil Defence, such as the individual dose meter, measure either roentgens or roentgens per hour depending on whether they measure the total radiation dose or the radiation dose rate. The exception is the Contamination Meter, which gives an indication of small traces of radioactivity, and is concerned with measuring the amount of radioactivity contamination. This is measured in curies (or milli-curies or micro-curies as the case may be).

21. **Radiation Syndrome**

(i) *Acute:* Radiation sickness is seen in its most characteristic form in individuals who have been exposed to external body radiation at the moment of explosion. Acute symptoms are unlikely to arise from exposure to fission products unless the area is highly contaminated and exposure is early and sufficiently lengthy.

The most severe cases develop symptoms and signs of deep shock, with extreme weakness and vomiting, within a few hours of exposure. With a lesser dose the onset of symptoms may not be apparent for some days ; varying degrees of shock are then noted, with vomiting, rising fever and marked weakness. Those who survive for some time may later show signs of damage to the blood system, gastric and intestinal disturbances supervene, and infection is common.

The least severe cases may not develop symptoms until after the third week, and in these recovery is the rule; similarly, patients who survive to the sixth week have a good chance of recovery. One of the most characteristic signs of radiation sickness seen in these cases, as well as in victims who survive for ten days or longer, is falling out of the hair, usually confined to the scalp but sometimes affecting the eyebrows or beard ; re-growth of hair occurs in three or four months.

Some of the more serious complications of radiation sickness are due to damage to the bone marrow, from which most of the normal constituents of the blood originate. This damage affects the production of both white and red blood cells, with a resulting diminution of their numbers in the circulation. As the white blood cells play a vital part in the defence of the body against bacteria, their absence or diminution in the circulation enables these bacteria to gain the upper hand, and infection may be widespread. Similarly, the diminution in the number of red blood cells gives rise, very often, to severe anaemia or bloodlessness—a condition which is aggravated by the tendency to bleeding which is a common feature of the disease. The cause of death is usually a combination of infection, loss of blood and anaemia.

(ii) *Chronic :* As at present defined, for peace time occupations, the maximum permissible dose rate for repeated exposures, is 0.1 roentgen per 8-hour day, or 0.5 roentgen per week.* (For a definition of roentgen which is the unit of measurement for a radioactive dose, see Appendix II.)

Repeated exposures, over long continuous periods, to daily dose rates considerably in excess of those quoted above may result in symptoms of chronic radiation sickness as shown by gastro-intestinal discomfort, increasing weakness, and blood changes of varying degrees of severity. Repeated exposures to doses of 25 roentgens and above may give rise to sickness.

Under peace time conditions, as described in the preceding sub-paragraph, there is no risk of sterility occurring. Under war time conditions, where increased risks may have to be taken in the course of urgent operations, a risk of temporary sterility may arise. It should be noted, however, that the close investigations which have been, and are, in fact, still being conducted in the two Japanese cities of Hiroshima and Nagasaki, show clearly that this is a purely temporary phase.

Chronic skin conditions may also arise if radioactive material is left in contact with the skin or is otherwise carried on the person for prolonged periods.

First aid Treatment : Treatment for shock is most important, as well as for any other injuries sustained. Complete physical and mental rest are of the greatest importance together with careful control of environmental temperatures to prevent chilling, and scrupulous care to prevent infection through any wounds. Many casualties will be suffering from radiation sickness and external wounds ; and a reduced blood formation lays the body open to wound infection. The skin of radiation victims is very susceptible to heat and great care will be necessary in the use of hot water bottles and other sources of heat. If radioactive contamination is suspected, cleansing will be necessary before admission to a First Aid Post or Hospital.

Chronic conditions are soon recognised if the cause is known or suspected. These cases should be referred to appropriate medical centres ; treatment of the condition and avoidance of further exposure are usually followed by a steady recovery, but periodical medical examinations may be necessary in certain cases. Reference is made only to first aid treatment in this pamphlet. There is much that can be done on the medical side to cure and mitigate the effects which are described. These measures will be made known in the most appropriate way to all those who require this medical and technical knowledge.

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* *Note :*—A dose rate of 0.5 roentgen per week represents the dose which can be tolerated, without ill effect, for a period of at least 60 years assuming an exposure of the whole body.

22. Radioactivity Poisoning

This term is used to describe the results that may follow the introduction of radioactive materials into the body, where they will act as local or systemic poisons due to the emission of damaging radiations. These radioactive materials may gain entrance into the body in various ways; e.g. :—

(*a*) By inhalation in the absence of a respirator.

(*b*) By ingestion, or entrance by the mouth through contaminated food, water, pipes, cigarettes, etc.

(*c*) By injection, or entrance into the circulation through contaminated wounds, abrasions or otherwise damaged skin.

The symptoms that may follow the entrance of radioactive material into the body may be of rapid onset if the dose is very large; more often it is slow and subtle in development, possibly extending over a period of months or even years. The effects may be localised to one part of the body (e.g., lungs, skin, etc.) or they may become systemic and give rise to general constitutional disturbances.

As these radioactive materials are effective in extremely minute quantities, prevention is obviously the only line to adopt. This is effected by a well-fitting respirator, hood, and adequate protective clothing; and by the avoidance of all food, drink or smoking while in a contaminated condition, and the observance of a strict working and cleansing discipline.

First aid is only applicable to personnel who may sustain cuts or wounds while working under contaminated conditions; when this occurs, the damaged skin should be flushed freely with running water and encouraged to bleed.

CHAPTER IV

BLAST

27. Effects on Persons

The direct effects of blast from high air burst bombs on persons is less than might be expected and serious internal injury is rare. The bulk of the casualties will be secondary due to injuries from falling masonry and flying debris. Such injuries would occur up to 1½-2 miles and to a lesser extent from glass and other flying debris at greater distances. The greatest number of indirect injuries and of deaths is likely to be caused by collapse of buildings due to blast with the survivors possibly trapped and exposed to fire dangers. It has been estimated that 70 per cent. of all casualties would suffer from physical injury of some sort.

Protection against blast would not present an insoluble problem. Japanese air raid shelters, even of poor construction, stood up well and underground shelters were a complete protection. Shelters could be constructed to resist both blast and gamma rays.

28. Effects on Material

From air burst bombs the blast wave is from above downwards and strikes roofs first, and near the centre of the damaged area buildings are collapsed or, with specially strong buildings, roofs are crushed in or dished even where the walls remain standing. Further away, where the blast wave is becoming more horizontal, buildings are pushed over or distorted.

The type of building and the distance from ground zero are the factors influencing reaction to blast. Unframed buildings like ordinary dwelling houses suffer more severe damage than framed buildings, whether of reinforced concrete or steel, and buildings of earthquake-resisting construction remain practically undamaged at 2,000 feet from ground zero. Bridges, which are built to withstand vertical pressure, stand up to the blast much better than ordinary houses, which are not so constructed, though reflection from roads, rivers, etc., may cause displacement on the underside and is a point to be carefully watched.

The British Mission estimated that from a high air burst bomb such as was used in Japan, an ordinary British city with 15 houses and 45 persons to the acre would suffer damage to dwelling houses to a distance of 2 to 2½ miles from ground zero on the following scale:—

Nature of Damage	*Average Radius from Ground Zero and Number of Houses Involved*
Demolished or requiring demolition	1 mile 30,000 houses
Uninhabitable and requiring major repairs	1–1½ miles 35,000 houses
Temporarily uninhabitable but requiring only minor repairs	1½ miles—2 to 2½ miles 50,000—100,000 houses

This damage would affect the dwellings of 400,000 people and, even allowing for those who might be casualties and those who could return after minor repairs to their houses had been completed, or who did not have to leave their houses at all, some 100,000 persons would need rehousing, creating a very big Civil Defence problem. (See Fig. 7.)

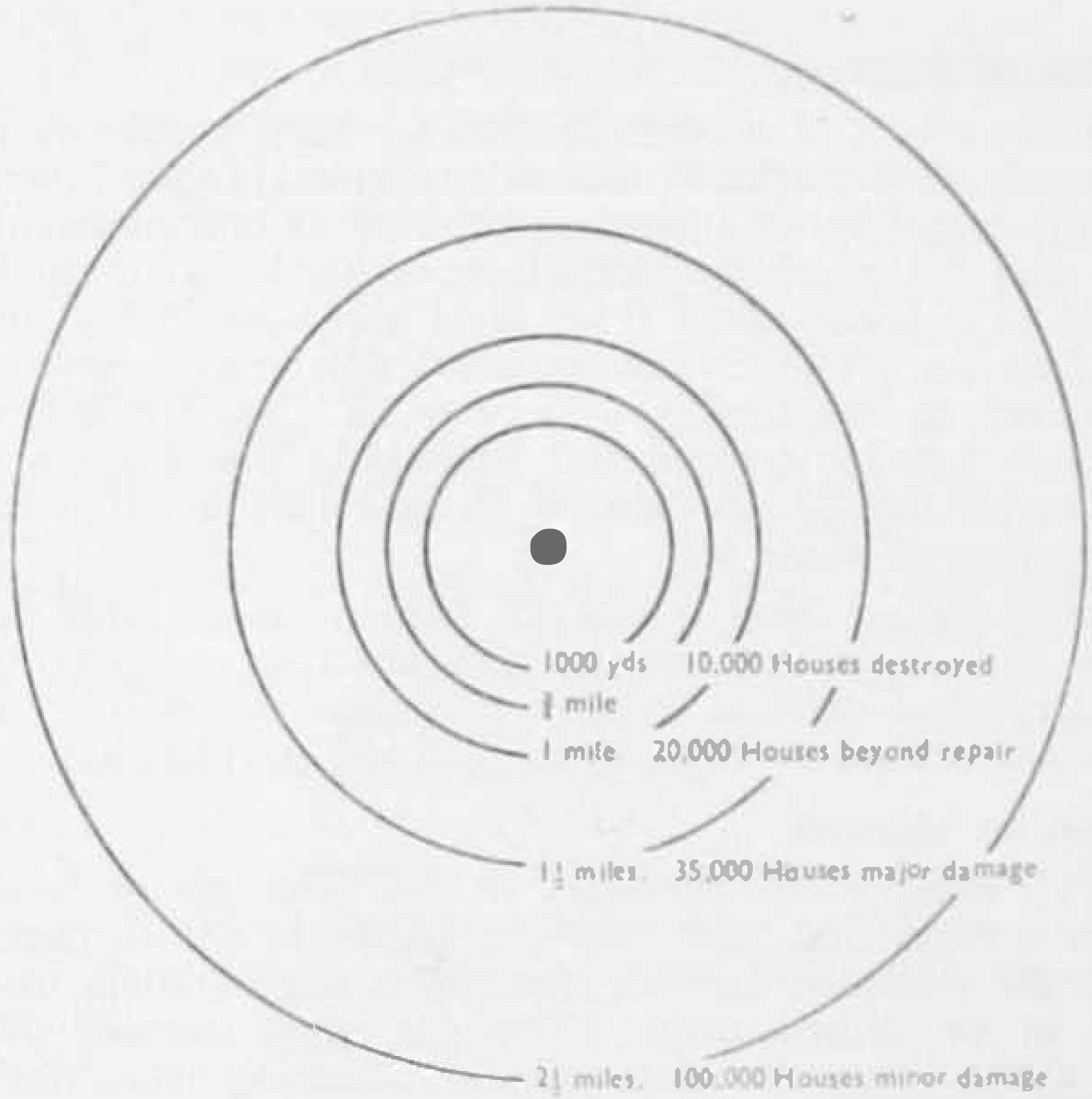


FIG. 7. Radii of Blast Damage.

29. Effects on Public Utility Services

The effects of the high air burst bomb on public utility services would be confined to damage above ground. Gas and water mains would be undamaged except possibly where they are carried over bridges. Sewers, too, should be all right. Over-ground installations such as gas holders, water pumping stations, electricity sub-stations, overhead electricity, tramway, telephone and telegraph cables, trams, buses and motor cars would be damaged more or less severely up to one mile or so from ground zero and would present a big problem of repair to the utility services. Railway and tramway tracks would probably remain intact but be affected by debris, adjacent fires, overturned rolling stock, etc. Ground burst or low air burst bombs would produce a cratering effect and earth shock involving considerable areas of underground damage, but the ground area affected would be much smaller. Delayed danger from induced radioactivity and fission products might, if present, also considerably complicate the work of repair.

30. Rescue Problems

Apart from fire one of the major problems would be rescue work, and it must be accepted that the effect of blast, as indeed was discovered during the last war, will inevitably produce large quantities of rubble and debris which will complicate the rescue problem.

Rescue work, as always, requires high discipline and technique, and it is clearly important that in any area the design and location of shelters should be carefully mapped beforehand and made available for rescue parties. The rescue parties should also familiarise themselves with the use of these maps, since after an explosion the ordinary landmarks may not be available and approach to any such shelters would almost certainly be difficult owing to the rubble and debris.

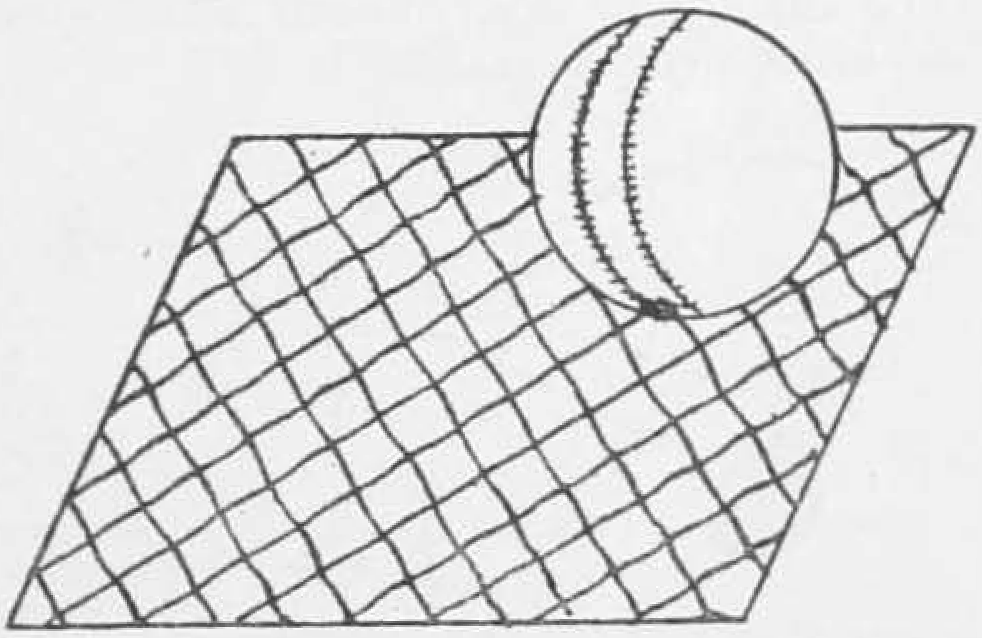
It will be of first importance to initiate some action with the greatest possible speed, even though full operations will take time to develop. Rescue parties with light equipment might be able, for example, to go straight in over the rubble and begin a preliminary reconnaissance and start rescue operations while the main force follows up. This force may require mechanical equipment to clear a path for their heavy vehicles, and the sooner people trapped in shelters have some evidence that help is arriving the better. In certain cases where conditions are suitable, it may be possible to make the quickest approach by water, and in studying this problem all these possibilities must be taken into account and training will be initiated in due course so as to prepare rescue parties and others to operate under conditions which may be quite unfamiliar at present.

APPENDIX I

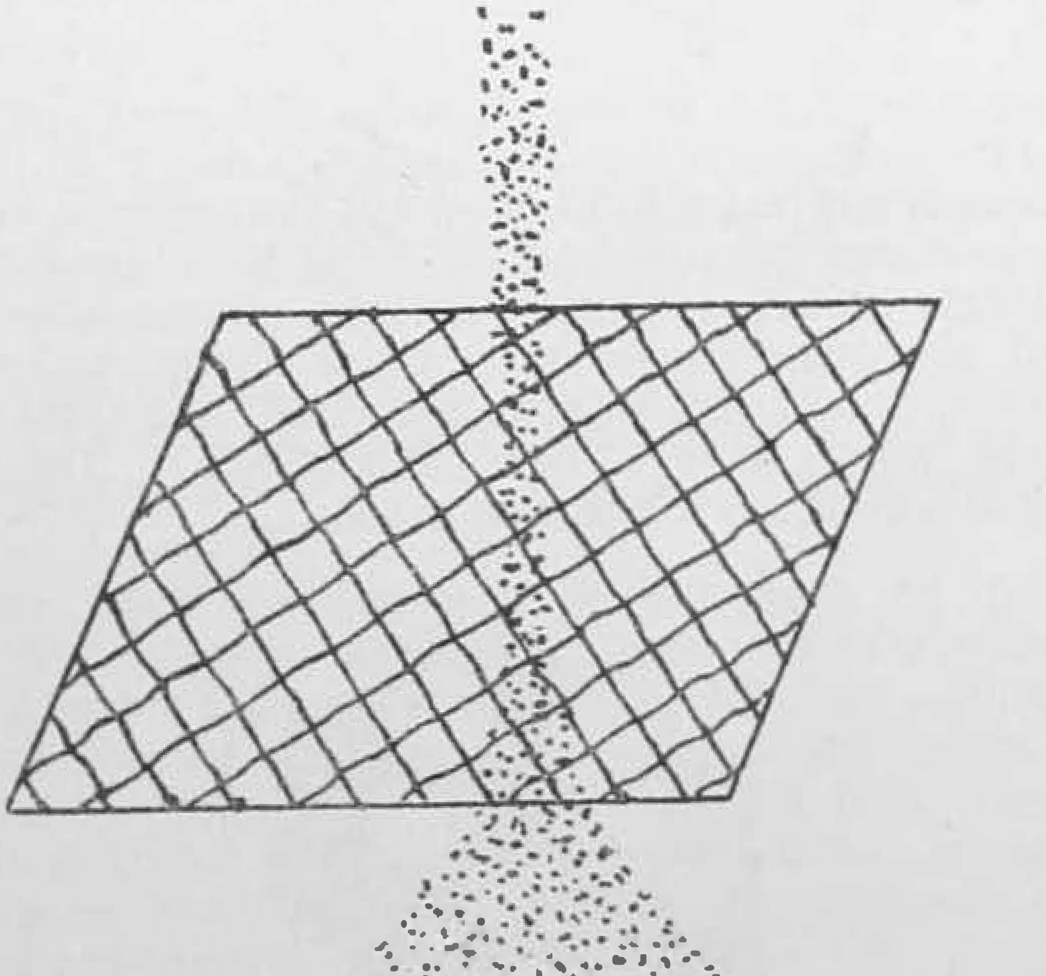
ELEMENTARY ATOMIC PHYSICS

1. The Structure of Matter in Relation to the Size of the Atom

In order to understand the way in which matter is built-up it must be realised that substances which we think of as solids in fact are not ; in other words matter is not continuous. From our point of view a very thin piece of steel, such as a safety razor blade, is solid ; from the point of view of the atom it is more akin to a piece of rabbit wire.



Wire stops ball as if it were solid.



Wire allows sand to pass through.

FIG. 8.

Now let us think about a piece of 1-inch mesh rabbit wire, first from the point of view of a cricket ball, and secondly from the point of view of a handful of dry sand. If a cricket ball falls on to the sheet of wire it will be stopped, and the cricket ball could scarcely be blamed if it said that the sheet of wire was a solid sheet. On the other hand if a handful of sand was dropped the grains of sand would fall through the sheet of wire ; true there would be collisions between the grains of sand and the wire, but none the less the sand would go through the wire, and the sand would not consider the wire sheet as being solid or continuous matter. (See Fig. 8.)

2. Structure of the Atom

The atom is composed of a " nucleus' and circling round it there are a number of small very light particles known as electrons each of which carries a negative electric charge. This set-up may be likened to our solar system with the sun as the counterpart of the nucleus and the earth, and other planets which revolve round it taking the place of the electrons. (See Fig. 9.)

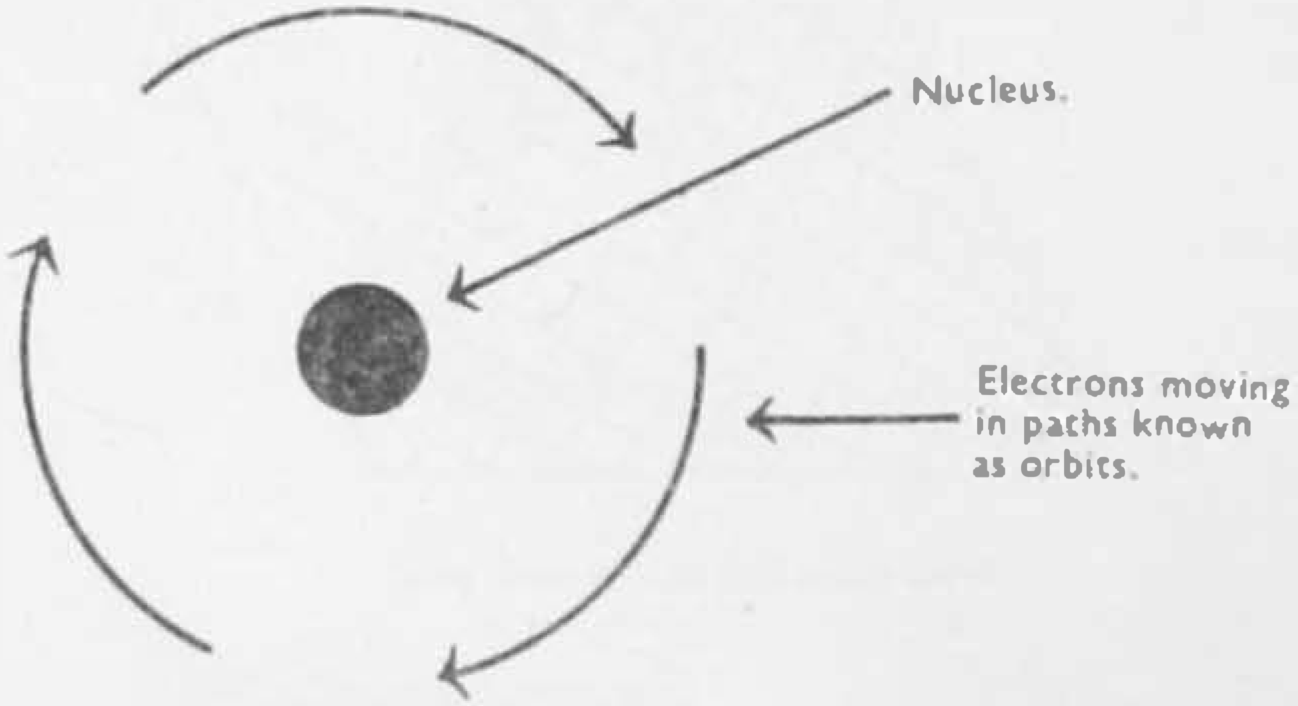


FIG. 9.

The nucleus is not just a solid lump but is composed of two kinds of particles held very strongly bunched together. (See Fig. 10.) One kind of particle carries a positive electric charge and is called a proton, and the other carries no electric charge and is called a neutron. Protons and neutrons are practically the same weight and both are very much heavier than the electron. The number of protons and electrons is such that as a whole the atom is electrically neutral.

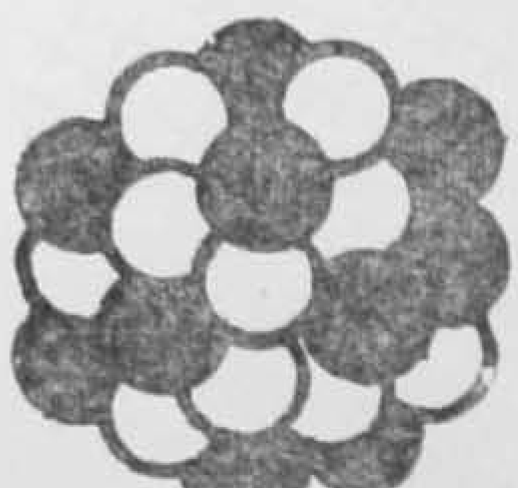


FIG. 10. Nucleus.

When atoms combine to form substances the nucleus of each atom remains unchanged but the orbits link-up. This is not unlike the situation caused when people link arms, having done so they have become a group having its own characteristics, yet the characteristics of each person remain unchanged. (See Figs. 11 and 12.)

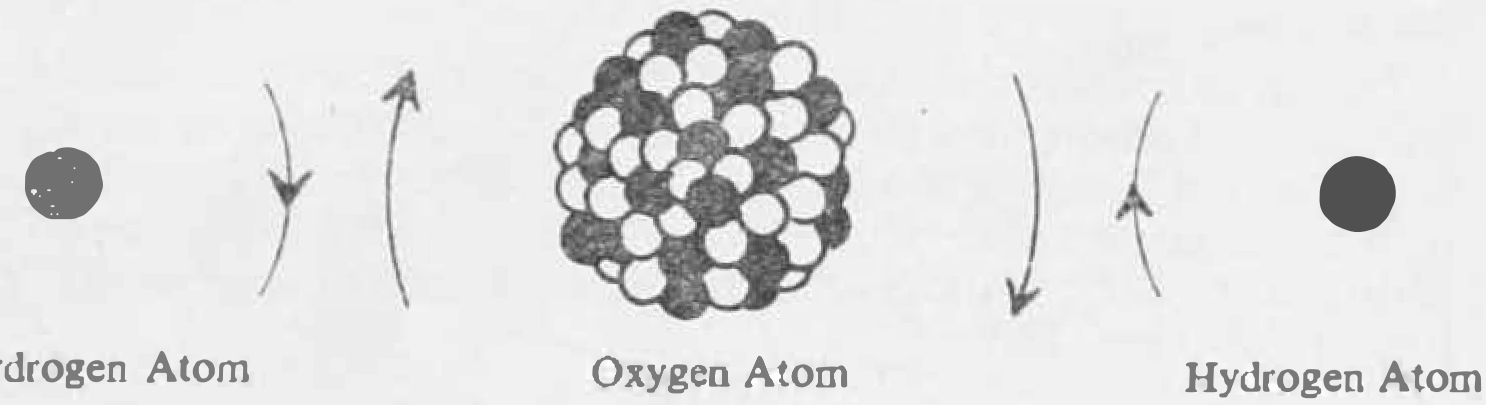
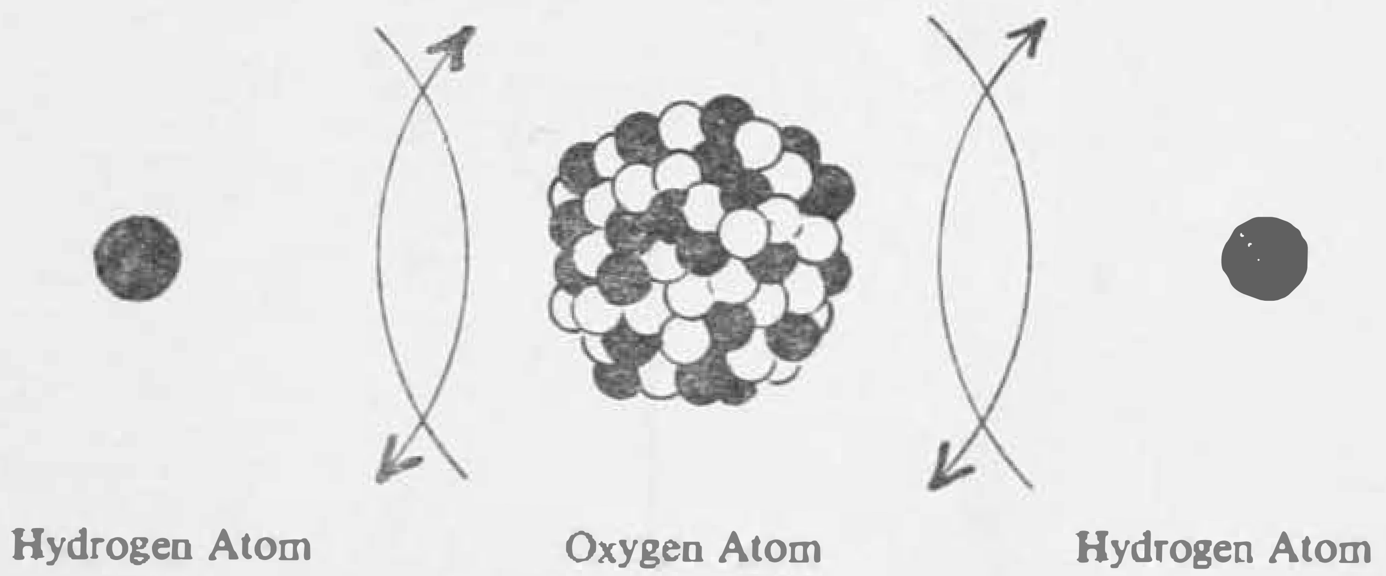


FIG. 11.



Linked-up (combined chemically) to form water.

FIG. 12.

Chemical reactions IN NO WAY AFFECT the nuclei of the atoms; they are brought about by the linking-up—or the unlinking—of electron orbits.

3. Radioactivity

It has long been known that some of the heavier elements emit radiations; such elements are said to be radioactive. The radiations come from the nuclei of the atoms and may be fast moving charged particles (alpha particles and electrons) and penetrating radiation similar to X-rays (gamma rays).

The radioactivity continues through many intermediate stages until finally all the atomic nuclei have changed into atoms which are quite stable. Thus radium—which is radioactive—ultimately becomes lead which is stable.

The time taken for this to happen depends on the element in question; for example—after 1,600 years half of a piece of radium will have become lead, after another 1,600 years only a quarter of the original amount will remain as radium and so on. This time is known as the "half-life"—for radium it is 1,600 years, for some elements it is only a fraction of a second whereas for others it may be millions of years. Under certain circumstances any element can become radioactive.

4. Neutrons

Because matter is not continuous and because the neutron is not electrically charged it can travel a long way in matter and, indeed, may pass right through it

5. **Fission**

Some neutrons when passing through matter will collide with a nucleus and when this takes places one of two things may happen: it may either bounce off and continue its journey, or it may be captured by the nucleus, that is, it may enter, and become part of, the nucleus.

The added mass and energy of the captured neutron causes the nucleus to become unstable (radioactive) and to restore its equilibrium may do one of two things; it may either emit radiations with or without neutrons, or with heavy elements, it may break in two and emit one or more neutrons; this process is known as fission. (See Figs. 13, 14 and 15.)

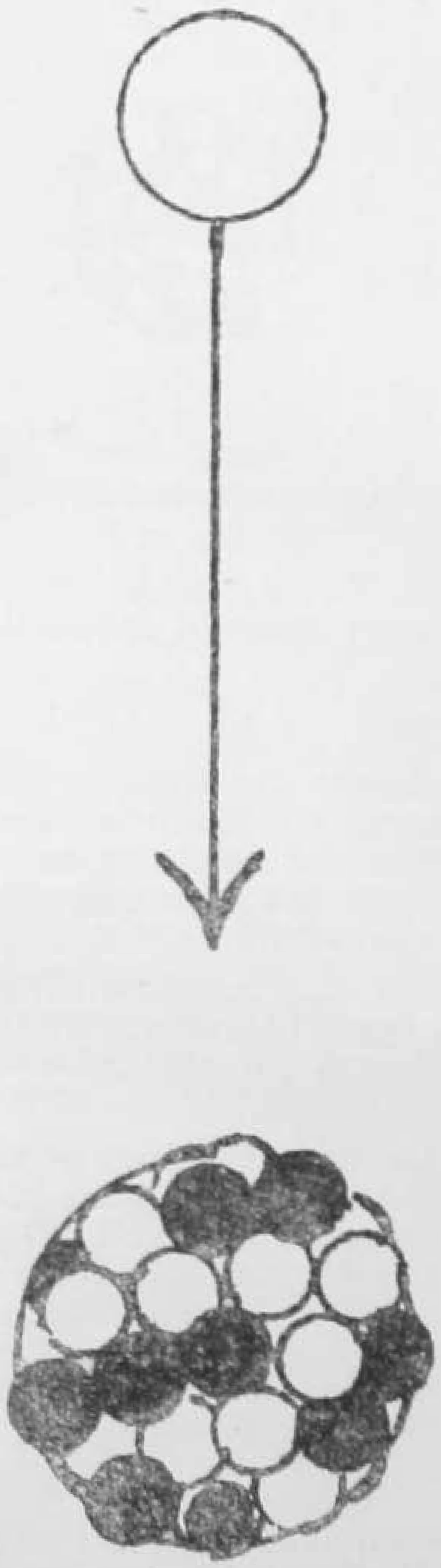


FIG. 13. Neutron about to enter nucleus

When fission takes place the energy released is enormous—if a pound of fissionable material could all be fissioned it would release as much energy as the explosion of 8,000 tons of T.N.T.

Some substances, after capturing a neutron, fission more easily than others: Uranium 235 and Plutonium markedly so. Fission is only observed in the heaviest elements.

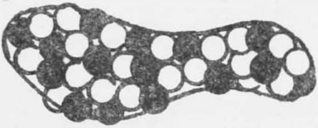


FIG. 14. Nucleus after neutron capture. Excess energy causes distortion; emission of radiations may restore equilibrium or the nucleus may fission.

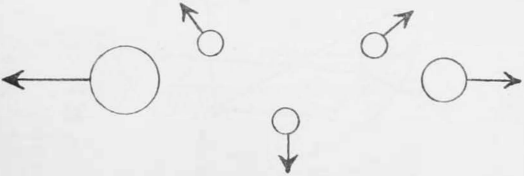


FIG. 15. After fission: the two fission fragments move apart, in this instance there are 3 fission neutrons.

6. Explosive Requirements

If this enormous energy release is to be used as an explosive the following requirements must be satisfied:—

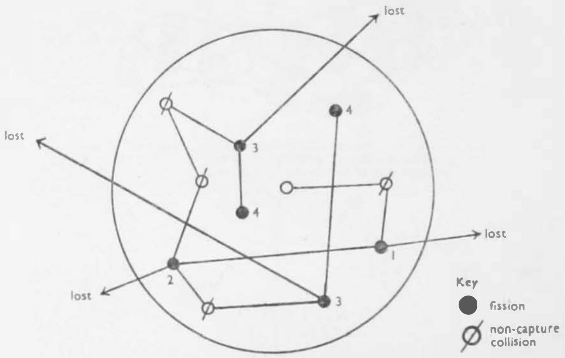
(*a*) The fission process must be capable of being initiated without the use of bulky and heavy apparatus.

(*b*) The fissioning of one nucleus must be capable of producing sufficient neutrons to propagate the process throughout the mass of fissionable material—that is to say it must start a chain reaction.

(*c*) The chain reaction must progress throughout the whole mass at such a speed that not only does it give rise to a rapid release of energy—a sine qua non of an explosion—but so rapidly that the mass of fissionable material is neither melted nor blown asunder before the bulk of it has had time to fission.

Below a certain size (the CRITICAL SIZE) a chain reaction cannot take place; above this size nothing can prevent it taking place. The existence of a critical size is due to the decreasing ratio of surface-volume as the size increases; by decreasing the mass of fissionable material the ratio surface-volume is increased and there is a greater possibility of neutron escape at the surface.

By using a sufficient mass of Uranium 235 or Plutonium, enough of the neutrons produced in fission will be utilised in producing further fissions to propagate the process throughout the mass of material; moreover, the process will proceed in such a small time that the result is an explosion. This time is of the order of a few micro-seconds—and a micro-second is one-millionth of a second. (See Fig. 16.)



The beginning of a fast-growing chain reaction

FIG. 16.

The figure gives a representation of the paths of neutrons in the initial stages of a chain reaction.

The chain started with fission 1 brought about by a neutron which started at 0 in the centre of the material. This fission gave two neutrons one of which was lost, the other causing fission 2. This fission gave rise to three neutrons one of which was lost, the other two causing fissions numbered 3, and so on. It can be seen that non-capture collisions are frequent as shown at ø. By the use of a reflector the build-up of the reaction would have been enhanced as some of the neutrons shown as lost might well have been reflected back into the mass.

7. The Atomic Bomb

From the above it follows that in principle the bomb may be made up as follows: The material used may be pure or reasonably pure Uranium 235 or Plutonium. It may be made up into two or more pieces each of which is sub-critical in size yet, when brought together are well above the critical mass—for the more material that is assembled together the less the proportional leakage of neutrons out of the mass and, therefore, the greater the increase of neutron intensity per generation and the more rapid the whole process.

With two sub-critical masses suitably apart no self-sustaining chain reaction can start ; when they are brought together nothing can prevent it starting. If they are brought together slowly the reaction will start as they approach each other and long before the whole mass has fissioned the material will have melted ; instead of an explosion comparable to that of thousands of tons of T.N.T. there will merely be an energy release sufficient to melt the assembly.

The whole should be encased in some dense material which will delay the expansion of the mass sufficiently to permit additional generations of fission before the process is brought to a stop by increasing size. (See Fig. 17.)

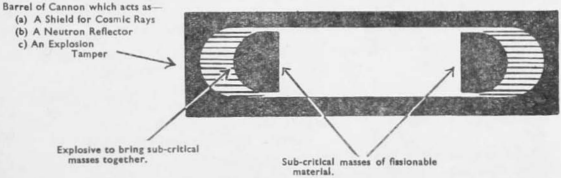


FIG. 17. Diagram illustrating Principle of Atomic Bomb.

APPENDIX II

GLOSSARY

ALPHA PARTICLE.—A helium nucleus (positively charged) travelling at high speed. Given out when atoms of Uranium, Radium and some other substances undergo spontaneous radioactive breakdown. Very short range and negligible penetrating power, e.g., stopped by a sheet of paper. Dangerous if emitted within the body, i.e., if Uranium or Radium, etc., is inhaled, swallowed or obtains entrance to the body through wounds.

ATOM.—Smallest unit of an element that retains the characteristics of that element.

BETA PARTICLES.—Fast electrons emitted when certain atoms undergo radioactive breakdown. Beta emitting substances can cause severe skin burns and are dangerous if they gain entrance to the body as with alpha emitters.

CHAIN REACTION.—Self-sustaining process in which some neutrons from one splitting atom are able to split more atoms, setting free still more neutrons which carry on the reaction indefinitely.

COSMIC RAYS.—Penetrating radiation coming to the earth from outer space.

CRITICAL SIZE.—The size of a piece of Uranium 235 or Plutonium which is just large enough to support a chain reaction within itself.

CURIE.—A unit of radioactivity approximately that associated with 1 gram of Radium.

DOSE.—The amount of radiation energy absorbed by a person. Measured in roentgens.

DOSE RATE.—The rate at which radiation is received. Measured in roentgens per hour.

ELECTRON.—The lightest known particle. A constituent of all atoms, around whose nuclei they revolve in orbits not unlike those of planets round the sun.

ELEMENT.—One of the basic substances which cannot be further decomposed into any other more basic substance by chemical means. Ninety-two elements are found naturally on the earth.

FALL-OUT.—The fall-out of fission products from the airborne cloud of radioactive material from a bomb resulting in the deposition of fission products on the ground.

FISSION.—The splitting of an atomic nucleus into two more or less equal fragments and a number of neutrons, with the liberation of a large amount of energy.

FISSION PRODUCTS.—Fragments produced when atoms undergo fission.

FIRE STORM.—A condition which may develop in a large area fire, if the uplift of the hot gases over the area is concentrated and powerful enough to produce a violent wind at the periphery ; this restricts the spread of fire outwards but intensifies the extent of combustion in the burning area.

FRISKING.—The passing of the probe of a Contamination Meter over the skin and clothing of a person. This will indicate the presence or absence of radioactive contamination.

GAMMA FLASH.—A phrase coined to distinguish the intense emission of gamma rays from an atomic explosion from the gamma rays given off by natural and induced radioactive substances and by fission products.

GAMMA RAYS.—Extremely penetrating radiation of very short wavelength. Can destroy living tissues and produce a number of physical effects, e.g., fluorescence, and chemical effects. X-rays are exactly the same radiation as low energy gamma rays, but are produced from special electrical machines.

GROUND ZERO.—That point at ground level vertically beneath the point of explosion of an atomic bomb. The greatest damage of all kinds is to be found here.

HALF LIFE.—The time taken for half the nuclei in a radioactive substance to disintegrate spontaneously—always constant for nuclei of the same sort. Varies from a few millionths of a second in the case of some materials to 10,000 million years for various types of nuclei.

HEAT FLASH.—The intense heat radiation emitted by an atomic bomb at the moment of explosion. Causes burns and primary fires over a wide area.

HOT AREA.—The area in which residual radioactivity may be detected after the explosion of an atomic bomb.

INDUCED RADIOACTIVITY.—Radioactivity induced in many materials by neutron bombardment as from the explosion of the atomic bomb.

NEUTRON.—One of the particles composing the nucleus of an atom. Approximately the same mass as a proton, but is electrically neutral. Has the property of penetration of all materials, and the rendering of many of them radioactive. Damages the human tissues.

NUCLEUS.—The " core " of an atom, where nearly all the mass is concentrated. Composed of protons and neutrons.

PERMISSIBLE DOSE.—The maximum total dose of radiation over any given period which is believed to cause no permanent ill effect to the body.

PLUTONIUM.—A metal of high atomic weight made by bombarding atoms of Uranium with neutrons. Can undergo fission and has replaced Uranium 235 in the later atomic bombs. Is a man-made element and was not found in nature until after it had been made artificially.

PROTON.—A positively charged particle found in the nuclei of all atoms.

RADIATION.—Energy in the form of electro-magnetic waves. May also be applied to beams of alpha particles, beta particles and neutrons.

RADIATION METERS.—Instruments of various kinds whose purpose is to detect radioactivity, and to measure radiation dose and radiation dose rate. Some record the total dose received up to any given moment; others record the rate at which that dose is being received per hour.

RADIATION SYNDROME.—A medical condition which follows any considerable amount of tissue damage caused by X or gamma rays, etc. Symptoms not usually perceptible until the passage of a few hours, or even of some days.

RADIOACTIVE POISONING.—The results which may follow the introduction of radioactive materials into the body.

RADIOACTIVITY.—The production of alpha or beta particles and gamma rays by the spontaneous breakdown of atomic nuclei; also as a result of the explosion of an atomic bomb.

ROENTGEN.—The measuring unit of radiation dose.

SCREENING.—Radiations are reduced in intensity on passing through matter. This phenomenon is known as screening.

SHIELDING.—See Screening.

URANIUM.—A heavy metal derived from naturally occurring ores, usually pitchblende. Normally the surface is a dark-yellowish brown colour. It has the highest atomic weight of the elements found in nature. Is mildly radioactive and contains 0.75 per cent. of Uranium 235.

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